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PHYSIOLOGICAL VARIATIONS IN WILD TURKEYS

and their

SIGNIFICANCE IN MANAGEMENT

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SIGNIFICANCE IN MANAGEMENT

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FOREWORD

Central Pennsylvania represents the northern limit of the eastern wild turkey's present range, and since the closing years of the nineteenth century, the Game Commission has earnestly strived constantly to main a shootable turkey population within the Commonwealth.

The difficulties encountered in these efforts have increased tremendously during recent years, both because of a vastly enlarged army of hunters and because of greatly improved methods of transportation, including numerous new woods roads, which render the forested areas readily accessible to the gunners. To offset them, the restocking of captive-reared birds was undertaken roughly ten years ago, and later numerous small refuges were created in the wild turkey counties.

The artificial propagation of wild turkeys which possess those same desirable sporting characteristics exhibited by the true wild birds is a most difficult matter. The experimental return to a system of cross-mating employed in a limited way by the Commission over twenty years ago appeared, however, to present a method of producing birds of the desired type, but before investing large sums of money for such purposes it was deemed wise to determine definitely whether or not birds so reared were actually superior to those produced by the usual methods.

The answer to this question could be found only by resorting to basic biological research, which the Commission was not at that time equipped to perform. A cooperative agreement was, therefore, made for the conduction of the work at the School of Forestry and Conservation of the University of Michigan, one of the country's oldest and best-known conservation organizations and one equipped with the most up-to-date research facilities suitable for use in the problem at hand.

Agents of the Commission's Divisions of Research and Propagation worked with representatives of the University in a series of physiological experiments combined with field checks of the results obtained. Though typical of a field of research heretofore barely more than touched upon by wildlife workers, the results obtained from the studies have proven most valuable in that they have clearly demonstrated three highly important points. First, that the cross-mated birds are definitely superior to those produced by common game farm methods; secondly, that the results obtained from basic physiological investigations can be practically applied in wildlife management; and thirdly, that state conservation departments can rely upon the nation's colleges and universities to furnish invaluable assistance in the form of basic research.

This bulletin describes both in popular and technical form the cooperative studies undertaken and completed. It is felt that they represent an important step in the Commission's turkey restoration program, and it is hoped that the report on them will prove both interesting and instructive.

Seth Gordon,
Executive Director.

Harrisburg, 1939

PART I

THE INHERENT "WILDNESS" OF DIFFERENT STRAINS OF WILD TURKEYS

By

Richard Gerstell

Introduction

Since the earliest days of colonization, the wild turkey has been closely associated with Pennsylvania history. It remains today in fair numbers and ranks with the black bear as one of the two most highly prized sporting trophies to be taken within the Commonwealth.

The bird originally native to the State was the true eastern wild turkey, *Meleagris gallopavo silvestris* (Vieillot), which Mosby (6) states was first technically described by Vieillot in 1817 from a Pennsylvania specimen.

The common domestic, or barnyard turkey, now so widely propagated, is generally believed to have arisen from the live-trapping and taming of the Merriam's turkey of Southwestern North America, *M. g. merriami* (Nelson). Limited numbers of these birds, which had been domesticated by the Indians, were taken to Europe by the early explorers. Later generations of them were brought back to the Atlantic seaboard colonies of America by the settlers.

Turned out to range on the pioneer farms, many of the domestic birds wandered off with the wild flocks and took up an abode in the forests. In addition, wild toms sometimes came close in around the farmyards and there mated with the tame hens. Thus, during the past three centuries, the present stock of wild turkeys has become hopelessly crossed with various domestic strains, with the ultimate result that it appears virtually certain that no absolutely pure strain wild turkeys are now to be found alive within the Commonwealth.

In spite of numerous generations of cross-breeding, however, there remained in Pennsylvania at the time the Game Commission was formed in 1895 a relatively small population of wild turkeys. The individual members of the group very closely resembled in all respects the original native species and were from the sportsman's viewpoint "genuinely wild." The population has gradually increased during the past forty years, principally through the protection offered by comparatively short open hunting seasons and a carefully planned and fully protected system of game refuges. At present it affords the hunters an annual legal kill totalling from 3,500 to 6,000 or more birds.

To aid its turkey management program, the Commission in 1929 established the State Wild Turkey Farm. Its purpose was annually to supply a comparatively large number of first quality wild turkeys for restocking depleted coverts.

The unit comprises approximately 1,200 acres of land in Lack Township, Juniata County, in the heart of Pennsylvania's portion of the wild turkey's present range. The central half of the area is surrounded by a woven wire fence nine feet in height. Within the enclosure are located the incubator and brooder houses, holding pens and other essentials of the propagating plant. They are surrounded by more than 600 acres of ideal mountain turkey range, including both cleared and wooded sections.

The original brood stock taken to the farm consisted of a flock of approximately 100 cross-bred, "semi-domesticated" turkeys, believed to have been built up principally with birds hatched from eggs illegally taken in the wild. The individual specimens all exhibited the chestnut-colored tail-band and other outstanding characteristics of the native eastern wild turkey. Their bodies were light and fusiform, their carriage erect. In short, except for the all important fact that they acted only "half-wild," they outwardly appeared to possess all the attributes of "genuine" wild turkeys.

Since 1929 over 11,000 individuals have been reared from the primary breeding stock. Practically all of them have been released for restocking purposes. Since severe culling and selective mating have been constantly practiced, the birds turned out have been of exceptional quality, at least as far as artificially propagated strains are concerned.

Since the establishment of the farm, one problem of major proportions has been constantly encountered in the restocking program. **In spite of special handling methods, including a carefully planned "hardening off" process, many of the birds planted evidenced that most desirable characteristic of "wildness" to only a limited degree.**

In some few cases, groups of birds were released at carefully selected sites far removed from human habitations where wild individuals were known to range. Instead of remaining in those sections, however, they shortly made their way to the nearest farms, where they were wont to remain in spite of numerous attempts to drive them back into the woods. In some instances, the same tendency was evidenced to a lesser degree, while in still others, the birds promptly reverted to the true wild type and the plantings proved highly successful.

In attempting to increase the degree of "wildness" exhibited by the birds raised at the Turkey Farm, the Commission in the spring of 1936 again resorted to the use of a principle which its first Secretary, Dr. Joseph Kalbfus, reported utilizing on a limited scale in 1912 (3). During the past few years the same system has been employed in Missouri, Virginia and possibly other states. It involves the confinement of unmated, "semi-domesticated," game farm females in open pens located in remote sections of the State's best turkey range. The wild toms in the vicinity fly into the enclosures and mate with the captive hens. Then, as fast as laid, the eggs are collected and taken to the Turkey Farm for incubation. The poults hatched from them are propagated in the same general manner as the regular farm stock arising from the mating of farm-reared males and females. Full details of this program have been described by Fluke (1), Luttringer (4) and Wessell (7).

Once under way, it was obvious to those persons connected with the newly undertaken program that the birds produced from the wild-mating areas were far superior to the straight game farm individuals in that they appeared to possess the factor of "wildness" to a far greater degree than did the latter.

The differences in the degree of wildness exhibited by the two classes of birds were readily observed shortly after hatching from the egg. When one placed a hand in an incubator tray containing ten-to-twelve-hour-old poults from the wild-mating areas and then shortly thereafter placed it in another section filled with game farm birds of the same age, hatched under identical conditions, **a slight but very definite difference in the reactions of the two groups was noted.** The mating area birds showed a tendency to pull away from the hand as if afraid of it, while the game farm individuals appeared completely unaware of its presence. When the poults were removed from the incubator and placed in carrying boxes ready for transportation to the brooder house, similar reactive differences were noted. The mating area peeps tended to duck and shy away from rapid movements made by the human handlers, while the game farm group evidenced little or no reaction to them. The same results were obtained when a slight sound was produced by scratching on the exterior surface of the containers. When birds of each class were placed on a table and induced to walk, the

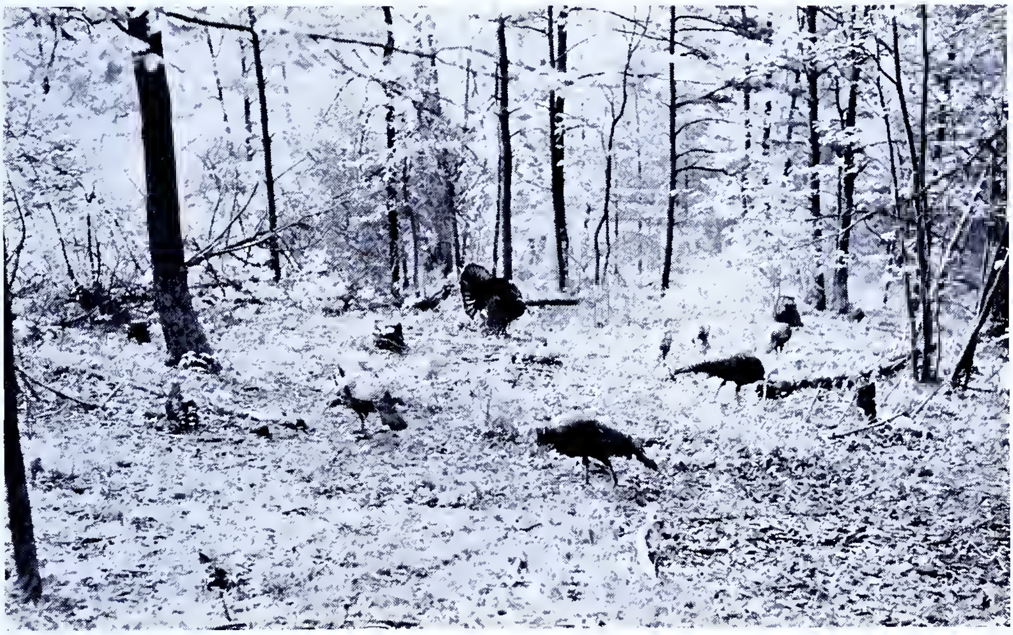

Figure 1. A wild gobbler with hens confined in a wilderness mating area.

movements of the area poults were found to be more rapid, more precise and far better coordinated than those of the farm group. Finally, a close examination of the eyes of members of both classifications revealed the fact that those of the area peeps appeared more "alert" than those of the farm poults.

All these differences were very slight, but highly significant beause they seemed clearly to indicate that if future turkey management practices are to prove successful, particularly insofar as restocking is concerned, we must gain some insight into the oft-repeated question, "What makes the wild turkey wild?"

In this respect the writer was quite fortunate in having an opportunity to discuss the observations outlined above with Professor H. M. Wight of the School of Forestry and Conservation of the University of Michigan, who was employed as a consultant during the summer of 1936 by the Pennsylvania Game Commission. He outlined a means whereby the differences under consideration could be accurately determined and measured.

The discussion led to the undertaking and completion during 1937 of a cooperative turkey research project sponsored by the Pennsylvania Game Commission and the School of Forestry and Conservation of the University of Michigan. The Zoology Department of the University, as well as other persons mentioned elsewhere in this publication, rendered valuable assistance in the work. The aim of the study was to determine the exact differences between birds of the game farm and wild-mating area classifications.

In the following paragraphs, the writer will attempt in a brief, nontechnical manner to outline the results of the studies completed and to point out how they may be practically applied in Pennsylvania's wild turkey management program. Elsewhere in this bulletin, William H. Long, graduate student at the University of Michigan, will render in technical form a complete report on the investigations.

It is hoped that the material presented may show the sportsman how the results obtained from detailed scientific investigation may be gainfully employed in practical game management and may point out to the game technician certain basic research methods to which he may advantageously resort.

In attempting to determine the inherent differences common to the mating area poults as compared to the game farm birds, it has been necessary to make a comparative study of the functioning of the various organs of the bodies of the two groups of birds. In technical terms, the investigations may be said to have been principally of a *physiological* nature.

The Eggs

To establish a basis for the research, it was deemed advisable to make a comparative study of the two groups of eggs. First, their parental source was considered. It was known that all the eggs were of the same derivation as far as female parentage was concerned, because they were produced in the bodies of, and laid by, game farm hens. All hereditary differences, therefore, could largely be attributed to the male parents. **The game farm poults, which for simplicity will hereafter be referred to as the "GF" birds, represented the tenth generation of game farm hens mated with game farm toms. The wild-mating area poults, which will later be referred to simply as the "WM" stock, were the offspring of game farm females crossed with wild males.**

In general appearance the two groups of eggs were quite similar, being a dull buff flecked with brown. Wide individual variations were noted in both groups and it was impossible to separate the two classications on the basis of color and markings.

In size also the two egg groups were found to be very similar, though the "WM" class averaged slightly smaller than the "GF" specimens. Since Marble and Margolf (5) found that during the second year of life, domestic turkey hens laid on the average slightly larger eggs than those they produced in their first season, and since the hens placed in the mating areas were for the most part one-year-old birds selected for their small size, slim body lines and other external characteristics of wild birds, while many of the game farm birds were over one year in age, the difference is readily accounted for and might well be expected. Based on the weight of 100 specimens from each group, recorded from three to five days after laying and kept at temperatures ranging from seventy to eighty degrees Fahrenheit, the average weight of one "WM" egg was found to be .141 pounds while that of one "GF" egg was .146 pounds. In this respect it is interesting to note that Marble and Margolf (5) found the average weight of eggs produced by pullet and yearling turkeys of two domestic strains was .196 and .207 pounds, respectively.

Having found that in external characteristics the two egg classes showed no significant differences, the next logical procedure was to analyze chemically their content, because it was from those substances within the egg that the embryos would have to be developed and fed during the period of incubation. The contents of five eggs (not including the shell) from each class were analyzed. In the case of the "WM" group, one was taken from each of five different mating areas. The results are listed below:*

Substances	*"WM" Eggs*	*"GF" Eggs*
Water	72.18%	74.53%
Protein	13.42%	12.55%
Fat	11.81%	10.47%
Carbohydrates	1.64%	1.53%
Ash	.95%	.92%
Phosphorus	.25%	.23%
Calcium	.11%	.06%

(Eggs kept at room temperatures of from 65° to 85° Fahrenheit until analyzed seven days after laying.)

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* Analysis through the courtesy of Pennsylvania Department of Agriculture, Bureau of Foods and Chemistry.

In this case again, the figures indicate that the two egg classes wer quite similar. It is, however, interesting to note that with the exception of water, the percentages of the various substances listed ar greater in the "WM" than in the "GF" eggs, but that the percentag of difference is in each instance relatively small. In fact, except a related to calcium content, it is quite probable that the variation are of no appreciable importance.

Because calcium, though usually present only in comparatively smal amounts, plays a most essential part in the life processes of all form of living animals, the difference in the relative amounts of the elemen found in the two egg groups appears worthy of consideration.

First of all, the ultimate origin of the difference is puzzling. Calciur was available to the turkeys both at the Game Farm and in the matin areas from two different sources, one primarily artificial, the othe natural. Both groups of birds were constantly furnished with cracke oyster shells designed to supply the element through artificial mean Also, the Turkey Farm and the mating areas afford natural supplie of the mineral in a common rock formation, soil, flora, fauna and wate supply. Why the two types of eggs produced by hens of the sam ancestry, held under much the same conditions, offered identical art ficial foods and allowed a similar range, should differ in this respec is unknown. Possibly the egg sample taken was so small that th difference was brought about by an unusual distribution of individua variations.

At any rate, the difference did exist and because of the element extreme importance in the scheme of animal life, further more detaile investigations might wisely and profitably be undertaken at som later date.

Since both varieties of eggs were incubated in the same machin under identical conditions of heat, humidity and light, we need not b concerned with the incubation process and may proceed with a con parative study of the stock produced from the two egg classes.

The Newly Hatched Poults

In general appearance, all the newly hatched poults of both type were practically identical, except for the fact that there was wid individual color variation exhibited in both groups. There was als a slight difference in the average size of the individuals composing th two classes, but this may readily be attributed to the difference i egg size already discussed. Based on the total weight of 100 ind viduals from each group twenty hours of age, the average weight c one "WM" poult was found to be .113 pounds, while the same figur for the "GF" birds was .116. Again, it may be of interest to compar these figures with those of domestic turkeys, which in the Whit Holland variety, Funk and Margolf (2) found to be .12 pounds.

As far as heredity is concerned, it has been pointed out that bot groups of poults possessed identical ancestry on the female side an that the essential difference lay in the paternal background. The "WM" peeps were the offspring of wild toms, while the "GF" individuals were produced by "half-wild," game farm gobblers. Thus, **since the male parents differed not primarily in appearance, but in their actions and reactions, any inherent differences in their offspring might be expectd to be found in those same characteristics.** Certain of them were noted in the comparative actions and reactions of the two groups of newly hatched poults described earlier, that is, in their reactions to a hand placed in the incubator, to quick movements, to noises, etc.

In view of these facts, it would appear logical to study on a comparative basis the functioning of the body organs, the natural reactions and the general behaviour of the two class types, because they appear to be representative of the primary differences between true wild turkeys and "half-wild" birds exhibiting the same outward appearance.

Seeking along these lines to discover significant internal variations which might account for the differences between the wild and the "half wild" birds, certain comparative tests were made when the poults were very young.

First of all, the body temperatures of the two groups of turkeys were taken. When removed from the incubator trays at an average age of approximately twelve hours, there was found to be a significant difference in the readings. Both bird groups had been subjected to hatching and drying temperatures of 103 degrees Fahrenheit (39.4 degrees Centigrade), but held in the hand at a room temperature of 83 to 85 degrees Fahrenheit, the average body temperature, as recorded by a standardized clinical thermometer inserted in the mouth and then down into the gizzard, was found to be 102.5 degrees Fahrenheit (39.2 degrees Centigrade) in the case of the "WM" poults as compared to 102.3 degrees Fahrenheit (39.1 degrees Centigrade) in the case of the "GF" individuals. This average was obtained from twenty readings in each group of birds, ten of which were taken from one hatch and a like number from a second which occurred several days later. Very slight individual temperature differences were noted, but the lowest record from the "WM" group was above the highest reading obtained from the "GF" classification.

Also at an average age of approximately twelve hours, a measurement of the respiratory rate was taken. This was done by holding the poults in the hand and counting the respiratory movements. The average body temperature of the two bird groups was as given above, while the room temperature approximated eighty-eight degrees Fahrenheit.

It is well realized that the count obtained was that of birds in a highly abnormal nervous condition and that certain movements other than those of a respiratory nature may have been inadvertently included in the records. The extent of error last mentioned probably was, however, quite small and fairly constant throughout both groups and so the figures obtained are presented because they are felt to be both of interest and significance.

The table below clearly indicates that under similar conditions the average respiratory rate of the two groups of birds varied appreciably, the "WM" individuals showing more rapid breathing. Also, the figures show that the two recorded extremes, both maximum and minimum, were higher in the "WM" individuals than in the "GF" peeps. Possibly the most interesting point, however, is that there is an apparent variation between groups of birds taken from different mating areas.

TABLE I

RESPIRATORY COUNTS

(See text for details of procedure)

Counts	"GF" Birds	"WM" Birds			
		For 3 Areas	Area No. 1	Area No. 6	Area No. 2
Number of Poults	59	57	19	20	18
Highest Record Per Minute	78	106	84	106	106
Lowest Record Per Minute	44	54	54	56	58
Average Per Minute....	68.6	74.0	68.4	76.2	81.1

The writer is inclined to wonder if the difference may not be proportional to the "wildness" of the various toms which mated with the hens in the several areas. For example, the gobbler which frequented Area No. 2 was exceptionally wary and seldom was seen. On the other hand, it is believed that the male which bred the females in Area No. 1 quite probably was a game farm bird released the year before. Thus, it is interesting to note carefully the respiratory figures for poults from Areas Nos. 1 and 2 and to compare the former with the records of the "GF" group. By so doing, it will be found that the average figure for the "GF" poults is approximately the same as for the individuals from Area No. 1, though the latter show higher extremes both maximum and minimum.

Body temperature and respiratory records such as those just discussed are of importance because they give some indication of the "internal condition" of any living animal. For example, during illness a constant check is made both of the body temperature and the pulse, or heart beat, which is closely allied to the rate of respiration. This is done because in them are reflected many internal conditions which could not otherwise be determined.

In all normal living animals there is constantly going on within the body a "building up" process known as anabolism and a "tearing down" process referred to as katabolism. The two are collectively termed metabolism, and in mature individuals they are more or less in a state of equilibrium, or balance. Though in a state of balance, the sum total of the two metabolic processes in one given animal may be far greater than the sum of the same two factors in another individual. For example, one animal may "build up" and "tear down" during a given period of time a total of ten units, but during the same period a second specimen may "build up" and "tear down" a total of fifty similar units. Assuming that a state of balance was maintained within the two bodies, the second would, therefore, be said to show a higher rate of metabolism than the first.

The differences noted in the temperature and respiratory rate of the two classes of turkey poults may possibly indicate that the "WM" birds have at the time of hatching a higher rate of metabolism than the "GF" individuals. This is of importance because, generally speaking, those animals showing the highest metabolic rates are the ones which are most active and show the greatest reaction to external stimuli of various sorts. From the sporting and management viewpoints, the most desirable turkeys certainly are those which are most active, alert, and quick to respond to any and all danger signals.

Since it was desirable accurately to determine the rate of metabolism and to measure the activity of the two groups of young turkeys and since the necessary apparatus was not available at the Turkey Farm, limited numbers of birds were sent for study purposes to the University of Michigan at Ann Arbor, Michigan, a distance of approximately 450 miles. Shipment was made by special delivery parcel post in small cardboard containers. The time required approximated twenty hours.

With special equipment, it was possible in the laboratories at Ann Arbor to make a large number of physiological tests designed to measure differences in the metabolism and muscular activity of turkey poults of the "WM" and "GF" classifications. From the practical viewpoint of the sportsman and game manager, the results obtained from the tests are of particular interest because many of them can be directly correlated with, and so help to interpret, various observations made in the field and at the Turkey Farm.

The Laboratory Studies

The apparatus used to carry out the metabolism studies was specially designed and extremely intricate. The determination of metabolic rates is based on the measurement of gaseous exchanges which take place within animal bodies. The results are commonly expressed in calories of heat produced. The whole subject is one which can be readily understood only by those with detailed scientific training and since the experiments conducted are fully discussed in the technical report presented in another section of this bulletin, suffice it to say at this point that the "WM" poults were found to exhibit a higher rate of metabolism than did the "GF" birds.

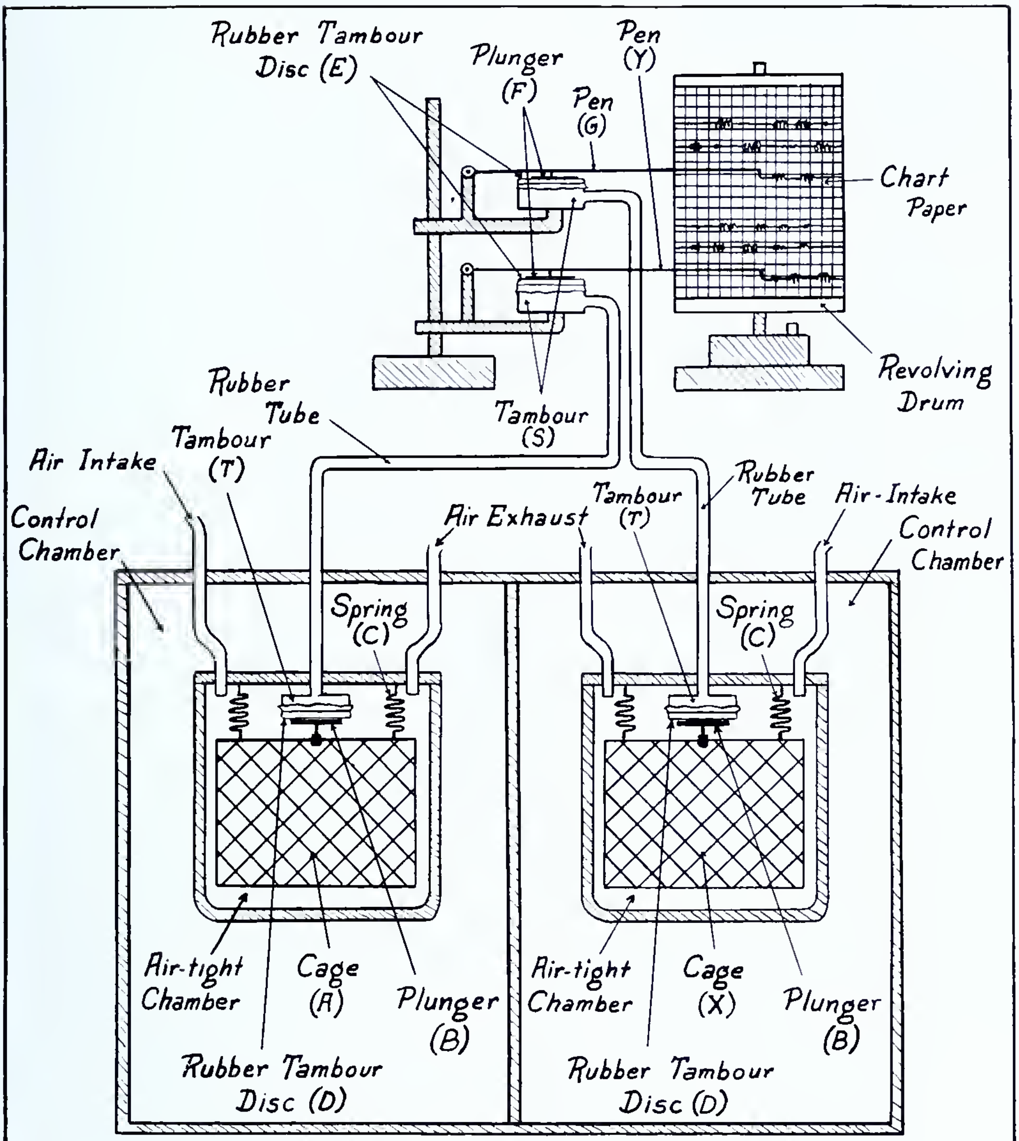
Since, as already stated, those animals exhibiting the highest metabolic rates are generally believed to show the greatest activity as well as reactions to various external stimuli, appreciable variation in the amount and intensity of the muscular activity of the two groups of turkeys might be expected. Such differences were not only found to exist, but were accurately measured. Certain of them are deemed to be of unusual practical importance and for that reason they will be discussed at length.

The activity recording device represented an inseparable part of the metabolism unit and the majority of the records were made while the birds were being subjected to metabolic tests. The principle employed therein is comparatively simple, but its application requires extremely exacting apparatus construction. The equipment accurately measures both the amount and intensity of muscular activity, though it must be pointed out that the activity is distinctly limited by the size of the cage in which the specimens are confined as well as by other factors. Thus, the records obtained from the machine cannot be considered the direct counterpart of the activity exhibited by the same individuals under natural conditions, though a close parallel may reasonably be expected.

A simplified diagram illustrating the methods used in obtaining the activity records is presented in Figure 2, page 11. The charts produced by means of the apparatus are technically known as kymograph records. One of these, Kymograph Record No. 1, is presented in Figure 3, page 12, to show the extreme sensitivity of the instrument. A careful study of the record will show the accuracy with which very slight muscular movements, such as that exhibited by a day-old poult in the act of "peeping," are recorded.

To prove of greatest value, it was necessary to conduct the metabolism tests under approved, standardized methods. These provide that the experimental animals must undergo a comparatively long period of fasting immediately prior to testing and that they must be subjected to darkness during the period of experimentation. Since light intensity and the presence, or absence, of food in the digestive tract are known to affect the amount and intensity of animal activity and since the majority, though not all, of the activity records herein discussed were taken at the same time the birds were being metabolically tested, the possible effects of these two factors must be afforded due consideration in studying the records.

Even casual observation clearly indicates that compared to domesticated varieties, the muscular activity of the "genuine" wild turkey is frequent, well coordinated and intensive. In their native haunts, both young and old are almost constantly active during the daylight hours. When frightened, they run through the thick underbrush, or fly through the treetops and soar to a distant hillside with unusual precision and almost unbelievable celerity. In seizing insects, berries, seeds and fruits with the beak, their movements are exceptionally precise and there is little or no "lost motion." Even in walking, they appear "to move all over." With each forward step, there is a rapid



PRINCIPLE EMPLOYED IN
MEASURING THE ACTIVITY OF
WILD TURKEY POULTS

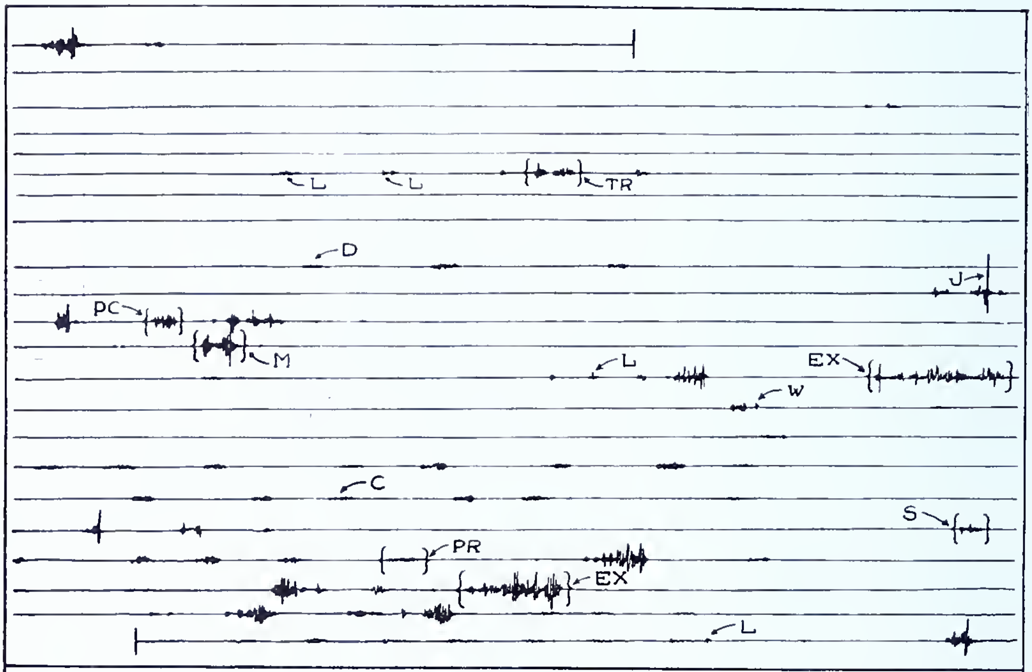
Specimens are placed in Cages (A) and (X). These are suspended by Springs (C) and have Plungers (B) attached. The Plungers (B) are snugly fitted against Rubber Tambour Discs (D) on the Tambours (T). Any movement of the specimens in the Cages (A) and (X) compresses the air in the Tambours (T). The compression in Tambours (T) is relayed through the Rubber Tubes to Tambours (S) which causes the Rubber Tambour Discs (E) to bulge, thus raising Plungers (F) and so causing Pens (G) and (Y) to produce verticle lines on the Chart Paper during periods of activity.

R. GERSTELL - '37

Figure 2.

extension and retraction of the head and neck such as that commonly portrayed by various mechanical toys and in animated motion picture cartoons. Outwardly it appears as if the birds' heads and necks were connected with their legs by large elastic bands. These same characteristics are not commonly exhibited by barnyard turkeys, which are usually comparatively inactive, slow-moving and "dull."

Differences of the type just mentioned were noted in the two groups of study poults immediately after hatching. They were also clearly demonstrated in the activity records compiled during the eight-week period of experimentation. For activity, the birds were tested on a comparative basis in pairs and in groups of four and eight, the "WM" and "GF" classifications being equally represented.

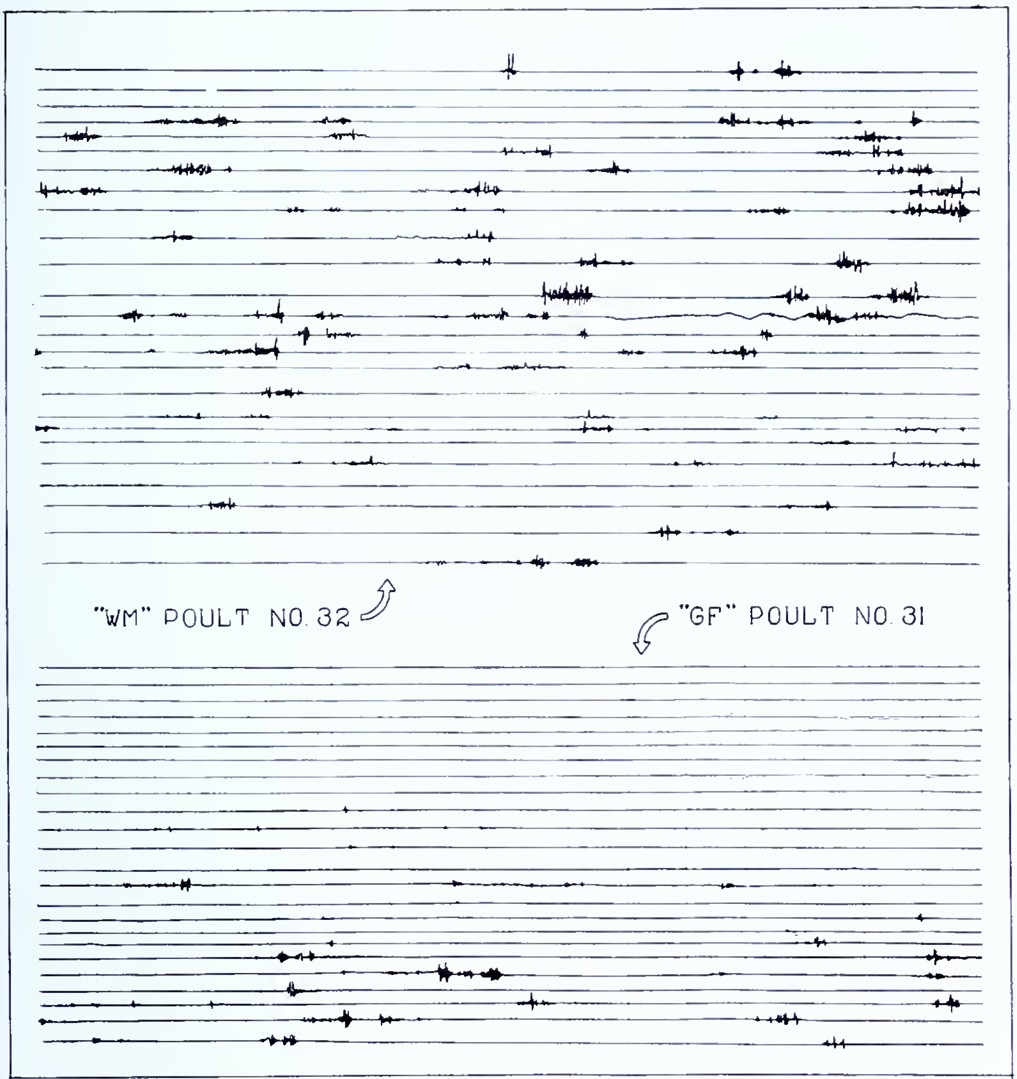


KYMOGRAPH RECORD NO. 1 (PARTIAL)

ILLUSTRATING RECORDED ACTIVITY OF A TURKEY POULT DURING A METABOLISM TEST IN THE LIGHT

LEGEND: HORIZONTAL LINES = INACTIVE PERIODS - VERTICAL LINES = ACTIVE PERIODS — C = VOCAL EXPRESSION — L = RAISING LEG — W = RAISING WING - M = STRETCHING — PR = PREENING — PC = PECKING AT CAGE — TR = TURNING AROUND IN CAGE — J = JUMPING — S = SQUATTING — D = DEFECATING — EX = EXTREME ACTIVITY

Figure 3.



KYMOGRAPH RECORD NO. 2 (PARTIAL)

COMPARING THE MUSCULAR ACTIVITY OF "WM" TURKEY POULT NO. 32 WITH THAT OF "GF" POULT NO. 31 AS RECORDED DURING A METABOLISM TEST

LEGEND HORIZONTAL LINES = INACTIVE PERIODS — VERTICAL LINES = ACTIVE PERIODS NOTE: BOTH BIRDS SIMULTANEOUSLY TESTED UNDER IDENTICAL CONDITIONS PRODUCED IN DUAL APPARATUS.

Figure 4.

As would naturally be expected, wide individual variation was found among specimens from each group. In certain instances, the most active of the "GF" poults was found to produce "higher" activity records than the least active of the "WM" class. On the other hand, the least alert of the "WM" birds rated far above the least active "GF" specimens. This was likewise true in the case of the most active individuals of the two classifications. A comparative record of the activity of two "superior" individuals, one from each group, will be found in Kymograph Record No. 2 presented in Figure 4, page 13.

Because of the individual variations encountered in the experiments, it has been necessary in drawing conclusions either to compare the best with the best, the mediums with mediums, and the least desirables with least desirables; or, better still, to consider all the records from the entire "WM" group with all the records from the entire "GF" group. The results of the latter comparison are summarized below.

TABLE II

A Comparison of the Activity of the Two Strains of Poults

(Summary)

Class Type	Activity Record (Hourly Basis)			
(All Ages from 1½ to 48 days)	Average Total Per Cent of Hour Spent in Activity	Average Number of Active Periods Per Hour	Average Frequency of Active Periods (in Seconds)	Average Duration of Single Active Period (in Seconds)
"GF" Poults	1.25%	90.7	39.7	0.51
"WM" Poults	2.17%	177.2	20.3	0.45

A detailed study of the summary will readily show that in many respects, the laboratory tests strongly tend to substantiate certain phases of the observational studies. First of all, the figures, which for convenience have been drawn up on an hourly basis, indicate that during an "average" hour, the "WM" turkey poults were active 2.17 per cent of the time, or nearly twice as much as the "GF" individuals, which show a similar percentage of only 1.25 per cent. These totals may appear unusually low, but the fact must be remembered that during most of the tests the birds were subjected to total darkness designed to keep activity at a minimum and that they were in a fasting state, having had no food for more than twenty-four hours. Similarly, the "WM" group showed on the average 177.2 active periods per hour as compared to only 90.7 periods for the "GF" birds. Also, the "WM" stock showed much more frequent periods of activity than did the "GF" class, the respective figures on average frequency being 20.3 and 39.7 seconds. Furthermore, the statistics would seem to indicate higher powers of coordination were exhibited by the "WM" peeps than by the "GF" poults, because on the average, the duration of each active period of the former class was shorter than that of the latter, the figures being 0.45 and 0.51 seconds, respectively.

Closely related to these points is the relative intensity of activity exhibited by the groups. No summary set of statistics has been compiled on this subject, but examination of several of the kymograph records will serve as illustrations. For example, in Kymograph Record No. 1 presented in Figure 3, page 12, the horizontal lines represent inactive and vertical lines active periods, as in all other records. The varying lengths of the vertical lines are, furthermore, indicative of the relative intensity of activity, the longer the lines, the greater the intensity. This may be clearly seen in the case of the comparatively short vertical lines representing a vocal expression and the much longer vertical deviations showing where the bird turned around in the cage, or jumped in the air. Similar study of Kymograph Record No. 2, Figure 4, page 13, which compares the muscular activity of "WM" poult number 32 with that of "GF" poult number 31, will plainly show that the vertical lines recorded by the former individual average appreciably longer than those produced by the latter. Similar differences may be observed in Kymograph Record No. 3, Figure 5, page 16. Thus, the records demonstrate that, generally speaking, the intensity of activity is greater in the "WM" than in the "GF" birds.

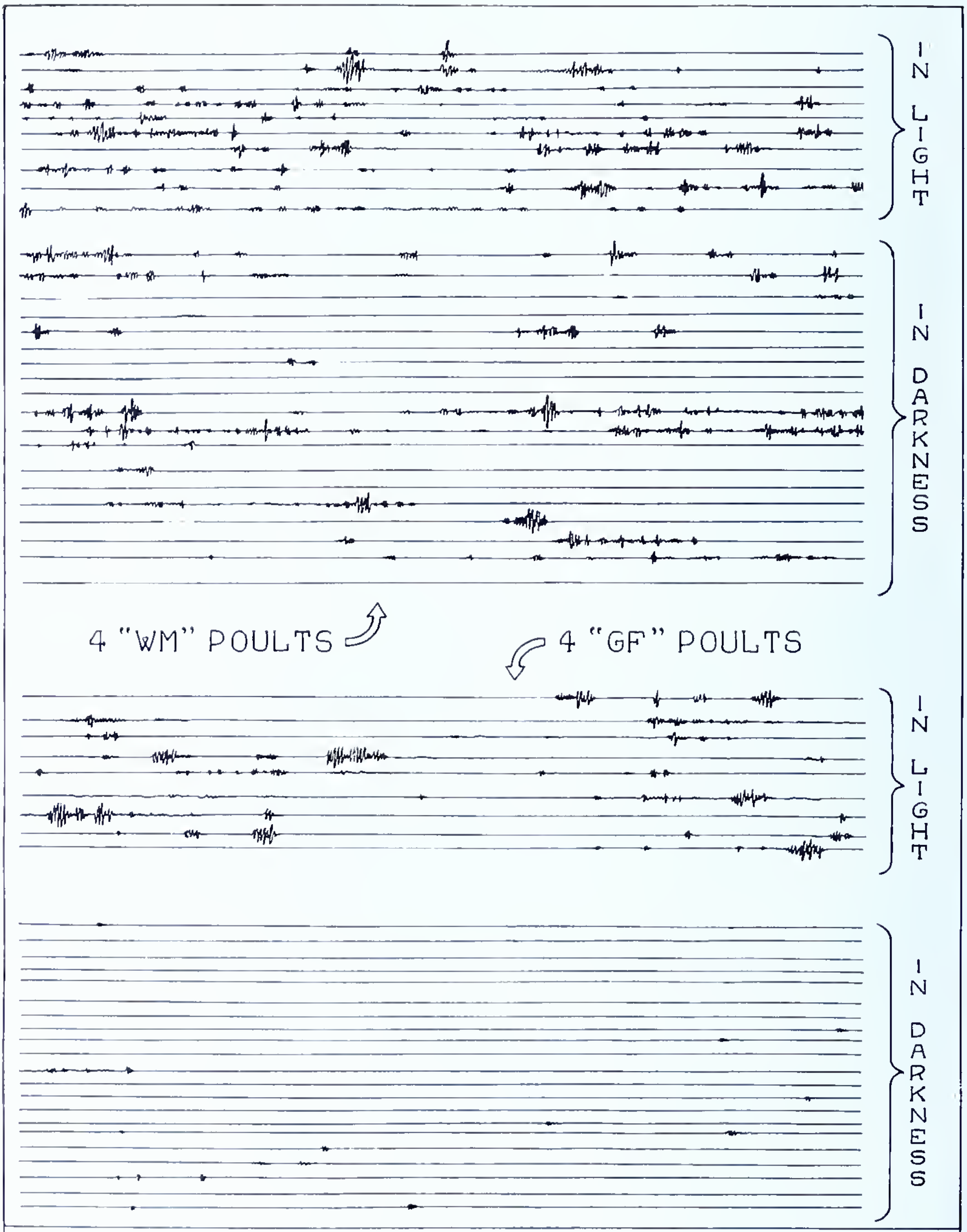
The extreme wariness of the "genuine" wild turkey is one of his most desirable sporting qualities. Birds which do not possess it to the highest degree are proportionally less desirable. One particular test clearly demonstrates the superiority of the "WM" poults over the "GF" birds in this respect.

When five days old, the activity of four "WM" turkeys was compared to that of four "GF" birds, both in darkness and in light. The results obtained from the test are presented in Kymograph Record No. 3, Figure 5, page 16. Study of this chart will reveal the fact that in the light the "WM" birds were somewhat more active than the "GF" individuals, but that in the dark they were many times more so. In fact, under the latter conditions, the activity of the "GF" group was almost entirely eliminated. For more detailed comparison, the results of this test are summarized in the table below.

TABLE III

COMPARATIVE EFFECTS OF LIGHT ON THE TWO STRAINS OF POULTS

Class Type	Activity Record (Hourly Basis)		
(All Birds 5 Days Old)	Average Total Per Cent of Hour Spent in Activity	Average Number of Active Periods Per Hour	Average Frequency of Active Periods (in Seconds)
(In Light)	(In Light)	(In Light)	(In Light)
4 "WM" Poults	15.5%	1110	3.2
4 "GF" Poults	7.8%	414	8.7
(In Dark)	(In Dark)	(In Dark)	(In Dark)
4 "WM" Poults	8.9%	676	5.3
4 "GF" Poults	1.0%	38	94.7



KYMOGRAPH RECORD NO. 3 (PARTIAL)

COMPARING THE RECORDED MUSCULAR ACTIVITY OF 4 "WM" TURKEY POULTS WITH THAT OF 4 "GF" POULTS BOTH IN LIGHT AND IN DARKNESS

LEGEND: HORIZONTAL LINES = INACTIVE PERIODS VERTICAL LINES = ACTIVE PERIODS. – NOTE: BOTH GROUPS OF BIRDS TESTED UNDER IDENTICAL CONDITIONS.

Figure 5.

This test becomes even more interesting when associated with certain observations recorded during the course of related field studies.

At an approximate age of sixteen weeks, a number of birds of both the "WM" and "GF" types were released for restocking purposes. In crating and shipment from the farm all the birds were subjected to identical treatment, but when the crates were opened to allow the birds their freedom, it was found that almost without exception the "WM" birds flew, while the "GF" birds merely ran or walked from the containers.

Furthermore, after release a careful check was made upon the activities of the planted birds. In the case of the "GF" stock, it was frequently found that the observer could watch the birds go to roost. Then, if due care were exercised, it was possible after dark to walk directly under the roosting birds without frightening them from the tree. In the case of the "WM" specimens, however, it was never possible to walk under the roost without "disturbing" the birds to such an extent that they flew in all directions from the tree.

Certainly this case shows the value of the laboratory tests inasmuch as the difference in question may be indicative of a survival factor of major importance. For example, particularly during that period spent in nesting on the ground, the wild turkey is subject to various predatory attacks and it may be that individuals of the "WM" strain would prove much less vulnerable to such assaults than would the "GF" birds.

In concluding the discussion of the results obtained from the laboratory tests, it may be well to add that, as pointed out in the technical report, those metabolism studies which involved unusually long periods wherein all food was withheld from the birds and they were subjected to varying temperatures appear to indicate that the "WM" birds are better able to withstand "hardships," such as lack of food, low temperatures and other adverse factors with which they might have to contend in the wild, than are the "GF" birds.

Aside from the physiological tests, there is still another point which would seem to strengthen the belief that the "WM" birds possess the inherent tendencies of "wildness" to a greater degree than do the "GF" individuals. This is the comparative rearing record for the two groups.

In attempting to raise naturally wild birds and mammals in captivity, the normal expectancy is that the wilder the individuals, the greater will be the propagating losses. Thus, it is interesting to note that during the season of 1937 a total of 1,787 "WM" and 1,647 "GF" poults were successfully hatched in the incubators and sent apparently in the best of condition to the brooders. Both groups of birds were propagated by mechanical means under identical conditions, but up to the time of release at an approximate age of sixteen weeks, the losses among the "WM" class totalled approximately thirty-eight per cent as compared to only twelve per cent in the "GF" type.

In the foregoing paragraphs, the writer has attempted to show that a strain of wild turkey poults arising from the crossing of "semi-domesticated," captive-reared females with wild males (herein re-

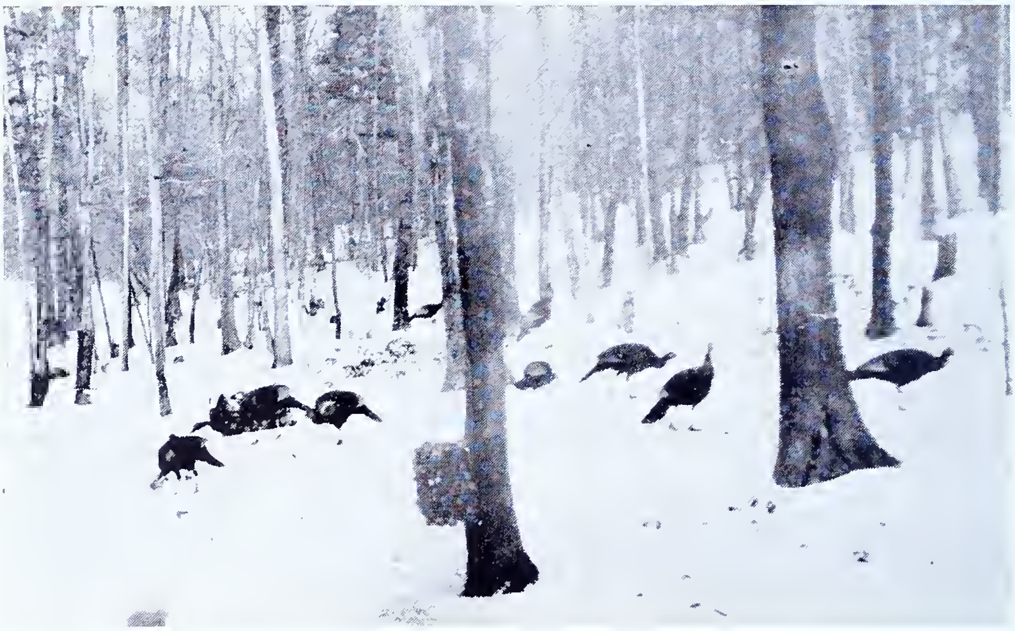


Figure 6. Wild turkeys at a winter feeding station.

ferred to as the "WM" group) possessed to a greater degree those characteristics commonly recognized as "wildness" than did a second strain of birds derived from the mating of similar "semi-domesticated," captive-reared females with males of the same sort (the so-called "GF" birds).

Granting that the differences discussed do exist, it is the duty of the game manager to gain all possible knowledge of the subject and to put it to practical use in his turkey management activities.

Practical Application

During recent years, those persons raising strains of turkeys of wild ancestry for restocking purposes have for the most part been inclined to concern themselves principally with the general appearance of the stock produced, rather than with its "wildness." It is quite likely that this attitude has been assumed chiefly because the majority of propagators not only did not know how to increase the degree of "wildness" in their flocks, but also were not in position to do so even had they had knowledge of the proper procedure.

By all means, strenuous efforts should be made to have artifically propagated strains of wild turkeys conform in appearance to what may be considered the "standard native type." These activities should, however, not be emphasized above certain other phases of the work, particularly the further development of true wild traits, because the sportsman is far more concerned with the "sporting characteristics" of his quarry than with the minute details of its appearance. He much prefers to kill a wary turkey, which has taxed his stalking, or calling, ability to the limit and which according to standards may be slightly "off color," than to "walk up and slaughter" a "tame" bird of perfect trophy appearance.

In the production of turkeys for restocking purposes, therefore, the problem is to release "wild" birds which will remain in the wilderness areas, reproduce the maximum possible numbers of their own kind, and provide true sport for the gunners. Thus, the propagator should strive both for desirable "trophy appearance" and for that even more important sporting quality termed "wildness." With respect to the latter, the fact must be realized that **in turkeys "wildness" is not only the result of parental education, association with other individuals, and reactions to environmental stimuli, but also of hereditary factors.**

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PART II

THE HEAT PRODUCTION AND MUSCULAR ACTIVITY OF TWO STRAINS OF WILD TURKEYS

By

William H. Long

Introduction

As described by Gerstell in the preceding section of this bulletin, two strains of wild turkey poults are recognized in this study. Both parents of one strain were game farm bred. This group is designated in this paper by the symbol "GF." The female parents of the second strain were game farm birds mated with wild toms. Individuals resulting from this cross are referred to as "WM" birds.

Eggs obtained from these two series of matings were mechanically incubated. At the time of hatching certain differences in their reaction to various stimuli were observed among the two groups of poults.

The purpose of the studies herein reported has been to measure and evaluate those variations which may be classed as physiological in origin. By using specially designed equipment, it has been possible to measure the variations both quantitatively and qualitatively.

The writer is greatly indebted for assistance to several members of the faculty of the University of Michigan, including particularly Dean S. T. Dana, Professor H. M. Wight, Dr. E. C. O'Roke, Dr. A. E. Woodward, and Dr. L. H. Newburgh; to Dr. H. H. Mitchell and Dr. S. C. Kendeigh, of the University of Illinois; and to Dr. W. B. Bell of the United States Bureau of Biological Survey.

Physiological Data

A comparative study of the physiology of two different strains of wild turkey poults presents a number of interesting problems which heretofore have not been presented in the science of wildlife management. These are of scientific as well as of practical interest to game managers and research workers. This report, therefore, represents a general comparison of the energy metabolism of two such groups of birds.

For the purpose of discussion and interpretation of experimental results, the poults have been classified into group types and age classes as follows:

GROUP TYPES

Game farm poults	GF
Wild-mating area poults	WM

AGE CLASSES

Class A	2- 3 days old
Class B	5- 9 days old
Class C	15-19 days old
Class D	28-36 days old
Class E	44-48 days old

The Embryo. Gerstell has briefly discussed the chemical analysis of the eggs from which the two strains of birds under consideration were hatched, but further reference to the matter seems at this point to be in order.

A discussion of the physiology and chemistry of the embryo of different kinds of domestic and wild birds is given by Groebbels (42, 43). Hasselbalch (46), Bohr (23), and Bohr and Hasselbalch (24) investigated the carbon dioxide production of the incubating domestic chick and found that carbon dioxide production increased with the weight of the growing embryo. Barott (4) measured the effect of temperature on heat elimination and gaseous exchange of hens' eggs and found that higher temperatures resulted in greater metabolism, more rapid development, earlier hatch, and at 100 degrees Fahrenheit, chicks superior in appearance and vitality. Mitchell and his associates (67) observed a burst of metabolic activity at hatching time in the domestic chick. At twenty days of age, the embryo produced 29 milligrams of carbon dioxide, but a chick just hatched produced during the first day 68 milligrams of carbon dioxide per hour. Other investigations of embryonic metabolism are discussed by Needham (70).

It is evident that the transformation of energy and the catabolism of carbohydrate, fat and protein substances of eggs are much better understood than the metabolism of the mineral substances such as phosphorous, sulphur, iron, and calcium.

One difference between the Area and Game Farm eggs which may be significant from a comparative point of view is the calcium content, this substance being about 50 per cent higher in the egg of the area turkeys than the farm birds.

Calcium is one of several inorganic structural substances playing an important role in body functions. Among these are the coagulation of blood, contractility of the heart, skeletal structure, eggshell formation, and muscular contractions.

The necessity for a sufficient amount of calcium and phosphorous in the body of animals has been pointed out by several investigators. According to Newburgh and MacKinnon (71), the metabolism of calcium and phosphorous in the body is profoundly influenced by the action of vitamin D. Thus, the presence of this vitamin in the body promotes normal growth of bones of the skeleton by increasing the retention of calcium and phosphorous.

The need of mineral elements and the role played by calcium in the nutrition of domestic fowl is discussed by Jull (50), Romanoff (83), and Buckner, Martin, and Peter (30), who show the deleterious effects on domestic fowl when the calcium level in the body is below normal.

Insko and Lyons (49) studied the influence of calcium and phosphorous on the developing bronze turkey embryo. Their data show a relatively slow increase in calcium until the seventeenth day, when the growth of the embryo was more rapid. A second rapid increase in calcium was also observed after the twentieth day.

Whether or not differences in the amount of diurnal activity shown by individual wild turkey poults are caused by or are the result of high or low amounts of calcium in the egg has not been determined. Buckner and his associates (31) investigated the calcium and phosphorous content of strong and weak chicks from hens with and without calcium carbonate in the diet. They segregated the hens into groups according to their access to oyster shell and free range. Some groups were given shell and allowed greater freedom than other groups that were confined and not given oyster shell, or confined and allowed oyster shell.

The chicks resulting from the eggs produced by the different groups of hens were classified according to their strength and weakness at the time of hatching. It was found that the stronger and more vigorous chicks contained more calcium and were those produced by hens that had been allowed more feeding range and more oyster shell.

The first observations indicating any difference in the two strains of poults, according to Gerstell, were made shortly after hatching. These observations apparently show that a more marked reaction to environment is manifested by the wild area poults.

Variations in muscular movements similar to those observed by Gerstell were noticed in the poults after arrival at the laboratory. The greatest degree of vigor was found in individuals of the WM group, which seemed to respond quicker and livelier to environmental stimulation. These differences were observed in such activities as jumping, running, crouching, fluttering of wings, stretching of legs, "bobbing" of the head, picking and fluffing feathers, scratching, attempted flying, and chirping or calling.

This last observation seems to agree fully with the observations of Phillips (74) on the wildness of young wild ducks hatched under hens. He compared the common "English Mallard" of the English game preserves to the wild mallard duck *(Anas boscas)* and found that the latter were much quicker on their feet than the common duck. He also observed the differences in the behavior of young wild ducks, the offspring of different cross breedings, where the common tame mallard was mated to the pure wild black duck *(Anas tristis.)*

Class A poults: 2-3 days old. The poults were about 30 hours old when they arrived at the University of Michigan laboratory. Certain individuals appeared to be in an abnormal physiological condition possibly because of exposure, during shipment, to temperatures lower than normally provided for newly hatched birds.

The poults were weighed immediately upon arrival, and it was found that each bird had lost an average of four grams in weight. Internal temperature readings were taken and respiration counts also were recorded. The average results given in Table IV are based on individual five-minute observations of temperature and respiration at a room temperature of 72 degrees Fahrenheit.

TABLE IV

The Internal Temperature and Respiratory Rate of Class A Poults

Number of Poults	Type Poult	Average Internal Temperatures						Average Respiration Per Minute		
		30 Hrs. Old		54 Hrs. Old		78 Hrs. Old		30 Hrs. Old	54 Hrs. Old	78 Hrs. Old
		°C	°F	°C	°F	°C	°F			
16	GF	39.3	102.4	39.8	103.7	40.2	104.4	46	43	40
8	WM	38.6	101.5	39.0	102.2	39.7	103.5	45	45	45

The averages given in Table IV represent individual temperature variations covering a relatively wide range. For example, one poult had a body temperature of 38.2 degrees Centigrade (100.8 degrees Fahrenheit) and a respiration rate of 28 per minute. This bird was extremely weak. Several of the poults had rather high temperatures which seemed to be correlated with higher respiration rates. Thus, a bird with a respiration rate of 70 per minute showed a body temperature of 39.7 degrees Centigrade (103.5 degrees Fahrenheit); another bird with a body temperature of 40.2 degrees Centigrade (104.4 degrees Fahrenheit) had a respiration rate of 68. The birds showing the highest body temperature and respiration rates, with one exception, were heavier in weight.

On the assumption that there might be some significance attached to the variations in body temperature and respiration in individual birds, they were marked for future identification and observation.

Following the initial examinations, the poults were removed to a brooding temperature of 100 degrees Fahrenheit for several hours, after which the brooder temperature was set at 96 degrees Fahrenheit, the temperature which was maintained throughout the early period of growth and also used when the metabolism was measured. After the ninth day the brooder and respiratory chamber temperatures were reduced to 90 degrees Fahrenheit.

Physiological examinations were again made on the first and second day after arrival. On the second, a pronounced increase was observed in the average body temperature. The results of these examinations are also reported in Table IV.

The internal temperature data for poults 12 hours (Gerstell) to three days after hatching indicate a relatively low degree of body heat.

These data are in agreement with earlier observations made by Long on young bobwhite, Hungarian partridge, and ring-neck pheasants, and with those of Leichtentritt (58), who concluded that newly hatched domestic chicks have an undeveloped temperature control.

A study of the heat production and muscular activity of 12 game farm poults and 12 area poults was made prior to their feeding. A respiratory quotient of 0.72 and a chamber temperature of 35.5 degrees Centigrade (95.9 degrees Fahrenheit) were assumed to be experimentally correct. This seemed permissable in view of the recent studies of the metabolism of domestic chicks between 10 and 100 hours of age, made by Barott, Byerly, and Pringle (5). The assumption seems also to be substantiated by the results published by Bohr and Hasselbalch (24), who measured the carbon dioxide production of domestic chick embryos. A respiratory quotient of 0.9 was found on the fifth day of incubation, and on the ninth day a quotient of 0.71 was observed, this quotient remaining constant thereafter. It was believed the last quotient indicated the metabolism of fat. Barott (4), measuring the energy metabolism of chick embryos, obtained somewhat similar results. He found the respiratory quotient dropped to 0.60 by the ninth day of incubation, but rose again to 0.66 by the eleventh day and remained fairly constant during the remainder of the incubation period. Shaw (85), investigating digestion in the domestic chick, found glycogen present in the liver on the twentieth day of incubation, but absent 24 hours after hatching.

Figure 7. Wild turkey poult twelve hours after hatching.

The results of the metabolism measurements of the young turkey poults are given in Table V.

TABLE V

THE ENERGY METABOLISM OF CLASS A POULTS

(Prior to any feeding and at 35.5°C. environmental temperature)

Number and Type of Poults	Body Temperature*	Respiration*	Average Body Weight	Average Daily Heat Production Per Poult		Average Activity Per Poult Per Hour	
				Total	Per Square Meter of Body Surface	Total	Active Periods
	°C	Per Minute	Grams	Calories	Calories	Per Cent	Number
4 GF	39.7	45	42.7	6.09	498	2.7	51
4 WM	39.2	43	42.4	5.86	482	1.6	55
4 GF			43.4	6.46	523	2.8	114
4 WM			43.2	5.90	479	1.8	156
4 GF			40.3	6.30	536	3.2	86
4 WM			38.2	6.15	543	2.7	84

* Average for class.

In each of six experiments, the metabolism of four poults of each type was measured under the conditions described. The average heat production, surface area, activity and body weight were determined by dividing the number of birds into the collective data for each item. An examination of the data in Table V shows the differences in the heat production of the two groups of poults obtained in multiple tests where four area poults were run against four game farm poults at the same time in separate chambers. The average body weight and body temperature were approximately the same for all poults of this age class. The differences in the total heat production for all experiments amounts to less than one-half a calory. The heat production per unit of surface area is of little comparative value, except that it seems to show a relatively low metabolism for poults of this age. The differences in the average muscular activity per bird per hour amounts to only 0.2 per cent, favoring the game farm birds. On the other hand, the area poults show about 9 per cent more active periods which occurred more frequently but lasted a shorter period of time than in the case of the game farm poults. In general, the observed average activity throughout the experiments substantiates in part the visual observations, i. e., individuals of the "WM" group apparently responded to environmental stimuli with quicker reflex movements of the body.

Class B poults: 5-9 days old. The poults were fed on the third day following the initial metabolism tests. Thus, metabolism measurements on the poults 5 to 9 days old were made only after they had fasted for at least 24 hours, during which time it was believed that any influence of digestion on heat production would be eliminated. This belief was substantiated by preliminary experiments in which the approximate rate of the passage of food through the digestive tract, from time of eating to time of egestion, was determined. The results of these experiments indicate, in general, that the rate of food passage decreased with age, length and capacity of the gastro-intestinal tract, and the type of food eaten. Thus, after the poults had been without food for 24 hours, one would expect a decrease in the amount of carbon dioxide produced and oxygen consumed. However, changes in the metabolic rate due to external activity would still be noticeable. Whether or not body temperature and muscular activity likewise decrease as a result of a 24-hour fast is a problem for later consideration. The data for the experiments with Class B poults is given in Table VI.

TABLE VI

THE ENERGY METABOLISM OF CLASS B POULTS

(24 hours after feeding and at 35.5°C. environmental temperature)

Number and Type of Poults	Body Temperature*	Respiration*	Average Body Weight	Average Daily Heat Production Per Poult		Average Activity Per Poult Per Hour	
				Total	Per Square Meter of Body Surface	Total	Active Periods
	°C	Per Minute	Grams	Calories	Calories	Per Cent	Number
2 GF	40.2	43	42.3	8.22	677	1.4	85
2 WM	40.1	48	44.2	8.77	702	1.3	77
4 GF			52.5	11.48	819	0.3	38
4 WM			59.5	12.92	850	2.3	167
1 GF			58.2	12.12	807	0.5	41
1 WM			63.3	13.76	866	0.7	54

* Average for class.

The measurement of the basal metabolism of selected poults from each group in age class B indicates that the average total heat production of the area birds is about 5.4 per cent higher than for the game farm birds. While the average activity records for all experiments in this age class are comparatively low, the area poults were nearly twice as active during the tests as were the game farm poults. Furthermore, the area poults' activity records show about 29 per cent more active periods.

Comparing the heat production on the basis of body surface, class B poults show a significant increase in the metabolic rate over the younger class A poults. The difference in body weight which normally accompanies an increase in size of developing birds shows that the older poults in class B on the average were 12 per cent heavier than class A poults.

A comparison of the poults in both age classes shows that under favorable conditions the average internal temperature of class B poults normally increased to a higher level by 0.8 degrees Centigrade over the younger class A birds. At the same time there was an average increase in activity of class B poults amounting to approximately 17 per cent. It was apparent that both types of poults were forming new habits and were becoming adjusted to new experiences and associations. It was obvious, however, that selected individuals in the area group in this age class were more sensitive to such changes. This difference in irritability was particularly observed in the experiments where 4 game farm and 4 area poults were compared. There seemed to be a pronounced difference in both the energy metabolism per square meter of body surface and muscular activity of the poults in this age class.

Class C poults: 15-19 days old. The experiments with poults in this group were conducted under the same conditions as in previous tests. The birds were carefully selected from each representative group with respect to body temperature, nervous stability, and general superior vigor. Due to the limited number of birds used in the experiments and to the repeated periods of fasting that they were necessarily subjected to in preparation for the metabolism tests, their normal growth may have been interfered with. Rest periods, while probably not of sufficient length, were allowed between experiments. Thus, the birds were allowed to recover some of the vitality lost during intermittent periods of fasting. Studies made of the loss in weight and fluctuations in body temperature resulting from a 24-hour (or longer) fast indicated that prolonged fasting markedly interefered with normal physiological processes. Indeed, it was noted that certain individual poults were in an unphysiological condition probably due to undernourishment and to an unbalanced nutritional state. Similar observations have been recorded for pigeons by Benedict and Riddle (18), who found that the heat production was greatly reduced during prolonged fasting. Kendeigh (53), working with starving passerine species, observed that a condition of under-nutrition was accompanied by a decrease in body temperature, which usually resulted in the death of the bird.

The metabolism measurements in this age class were of poults that had been allowed to eat for several days without experimental interruption, after which they were fasted for 24 hours. At this time the fecal discharges were of a whitish, watery consistency, lacking any solid particles. Previous to the tests a small suction tube was introduced first down the gullet into the crop, and then into the proventriculus and gizzard of these individuals to ascertain if the organs were empty. The results of these checks indicated the absence of food in the digestive tract from the crop to and including the gizzard. In view of these results, it was concluded that a respiratory quotient corresponding to the metabolism of fat might be expected.

A summary of the results for class C poults is given in Table VII. The average basal metabolism of the selected area poults, when measured at an environmental temperature of 32.2 degrees Centigrade (89.9 degrees Fahrenheit), is appreciably higher than the basal metabolism of the selected game farm poults of the same age and approximately the same weight. This increase in the heat production seems to be correlated with an increase in the average muscular activity of the area poults amounting to nearly 7 per cent per hour more than was recorded by the game farm poults. In general, the basal metabolism per unit of surface area seems highest in poults of this age, weight and size, when compared to younger and smaller poults from 2 to 9 days old.

TABLE VII

The Energy Metabolism of Class C Poults

(24 hours after feeding and at 32.2°C. environmental temperature)

Number and Type of Poults	Body Temperature*	Respiration*	Average Body Weight	CO_2 Production	Daily Heat Production	Average Activity Per Poult Per Hour	
				Total Per Hour†	Per Square Meter of Body Surface Per Day	Total	Active Periods
	°C	Per Minute	Grams	c.c.	Calories	Per Cent	Number
2 GF	40.7	52	80.7	102.9	864	0.2	26
2 WM	40.8	51	92.2	111.4	855	1.7	105
1 GF			95.6	116.5	873	2.3	273
1 WM			88.8	160.1	1261	9.8	885

* Average for class.

† Per poult.

The total number of active periods, their frequency of occurrence and average duration in seconds of experimental time are also significantly different. The percentage of total activity shows in Table VII that wild mated area birds were more active during the experiments than the game farm birds. On the average, the periods of activity occurred only once every 50 seconds in the case of the game farm poults, but the average occurrence of active periods of the area poults had a frequency of one active period every 13 seconds.

To illustrate the marked physiological difference between a game farm and an area poult, the respiratory and activity data of two such birds are given in Table VIII. No. 32, a wild-mated area poult, had earlier been observed to be more active, had a higher body temperature and respiration rate, and seemed to be somewhat more responsive to environmental stimulation than all other area poults. On the other hand, No. 31, a game farm bird, was likewilse a superior individual in its own group.

TABLE VIII

THE ENERGY METABOLISM OF TWO TURKEY POULTS 19 DAYS OLD

(24 hours after feeding and at 32.2°C. environmental temperature)

Type and Sex of Poult	Body Temperature	Body Weight	CO_2 Per Day	Heat Production Per 24 Hours		Activity Per Hour Per Bird			
				Total Per Day*	Per Square Meter Body Surface	Total	Active Periods	Frequency of Active Periods	Duration of Active Periods
Males	°C	Grams	Grams	Calories	Calories	Per Cent	Number	In Seconds	In Seconds
GF-31	40.7	95.6	5.49	18.25	873	2.3	273	13.2	0.3
WM-32	40.8	88.8	7.55	25.09	1261	9.8	885	4.1	0.4+
Experimental Difference		6.8	2.06	6.84	388	7.5	612	9.1	0.1+

* RQ 0.72.

When the metabolism of poults Nos. 31 and 32 was measured, two respiration chambers and two sets of activity recorders were used. The writing pens recorded the minimum and maximum muscular movements of each poult on the same kymograph record. It was interesting to observe visually, on the recording paper, the remarkable difference in both the total amount of activity and in the frequency of occurrence of the active periods. The comparative data are given in Table VIII. (Also see kymograph record No. 2, Gerstell, page 13.)

The differences in the basal metabolism and muscular activity of the two poults in this experiment are exceptionally significant. According to the data analysis, the total heat production of the area poult per 24 hours amounts to nearly 7 calories more than the game farm poult. The carbon dioxide production per hour of experiment amounts to approximately 27 per cent more for the area poult.

A satisfactory explanation of the increased metabolic rate of the area bird is probably due to the excessive amount of muscular activity (9.8 per cent) manifested by this bird per hour of experiment. Since both of the birds were selected because of superior vigor over other birds in their respective groups, it would be natural to expect a greater degree of activity in both birds.

The actual basal heat production of both poults is probably somewhat obscured by their activity, as the values are apparently high. Even though both poults were definitely in the post-absorptive state and in the dark, their activity was uncontrollable. If the experimental procedure later discussed (p. 52) had been followed, and if the metabolism had been measured at the time (after 6-7 p. m.) recommended by Benedict and Fox (12), the percentage of total activity and heat production might have been reduced.

In comparing the metabolism of the two poults per square meter of body surface, it is to be noted that the area bird shows an increase of 388 calories, or about 31 per cent over the less active game farm bird, regardless of the fact that both birds were the same age, approximately the same in size, and differed by not over 8 grams in body weight. Therefore, it is believed that the differences observed in the measured activity of the poults (about 52 per cent more for the wild-mated area poult) probably accounts for the pronounced difference in their metabolic rate.

Although some interesting data have been obtained with respect to the percentage of heat lost by the poults due to the vaporization of water, space does not permit their presentation in this report. The results of two experiments, however, are given where the heat production and water vapor output of a game farm bird and an area bird are compared. The heat lost from the body as water vapor, has been calculated by assuming that each gram of water vaporized by the poult represents 0.585 calories.

Kendeigh (53) investigated the loss in weight of English sparrows by observing the loss of moisture given off through the lungs and air sacs at different air temperatures from -1.1 degrees Centigrade (30.0 degrees Fahrenheit) to 36.1 degrees Centigrade (97.0 degrees Fahrenheit). He found that the amount of moisture lost through the respiratory system increased slowly with rising temperature, but above 29.7 degrees Centigrade (85.0 degrees Fahrenheit) the moisture output of the birds increased rapidly. Kayser (52) studied the heat production and heat loss of three pigeons at different air temperatures; at lower temperatures the birds produced on the average 1.489 grams of water, but at high temperatures the water loss increased to 2.45 grams. The moisture loss from the lungs was lower in saturated air than in dry air. The metabolism of domestic geese has been studied by Hari (45) at different air temperatures. His results show that the heat loss due to the vaporization of water amounted to about 50 per cent less at lower temperatures than at higher temperatures.

Mitchell and Kelley (69), in calculating the amount of water vaporized by different kinds of domestic birds, found a definite correlation between increasing temperature and the heat lost as water vapor. Dukes (36) measured the basal metabolism of hens fasting from 23 to 32 hours at temperatures ranging from 23.0 degrees Centigrade to 27.0 degrees Centigrade (73.4 degrees Fahrenheit to 80.6 degrees Fahrenheit) and found the heat lost in water vapor varied from 12 per cent to 25 per cent, averaging 17 per cent. He calls attention to the rather low average figure and believes it to be due to the influence of environmental temperature. Benedict, Landauer, and Fox (14) investigated the vaporization of water by two fasting domestic fowl. The environmental temperature during eight experiments ranged from

27.5 degrees Centigrade to 29.0 degrees Centigrade (81.5 degrees Fahrenheit to 84.2 degrees Fahrenheit). The ninth experiment was made at 16.8 degrees Centigrade (62.2 degrees Fahrenheit). They concluded for the series of all the experiments that, "The proportion of the total heat production lost in vaporization of water amounted to 49 per cent. . . ." A further analysis of their investigations shows that the birds which were tested in the thermic neutral zone of 28.0 degrees Centigrade (82.4 degrees Fahrenheit) averaged about 51.7 per cent of heat lost in water vapor, while those measured at the lower temperature lost about 33.1 per cent of heat in water vapor.

Since the vaporization of water is a continuous process and one involved in the control of body temperature, it is interesting to note in Table IX the role that the vaporizing process plays when correlated with the daily heat production per gram of body weight of the turkey poults. The area poult with a higher metabolism produced a greater amount of carbon dioxide and absorbed a greater amount of oxygen per hour than the game farm poult whose total activity was noticeably less than the other poult. The least active bird lost fifty-two and three-tenths per cent of its body heat in water vapor while the more active poult lost only thirty-nine and six tenths per cent. Benedict and his associates (12, 15) found that the vaporization of water by domestic fowl, particularly a male bird at 29.0 degrees Centigrade (84.2 degrees Fahrenheit) with an activity record of eleven percent, lost forty-five and seven-tenths per cent of its body heat in water vapor. In a second experiment made at 27.5 degrees Centigrade (81.5 degrees Fahrenheit) the same bird lost fifty and two-tenths per cent when active only four per cent of the experimental period.

TABLE IX

COMPARISON OF THE VAPORIZATION OF WATER AND THE ENERGY METABOLISM OF TWO FASTING TURKEY POULTS

	GF Poult	WM Poult
Initial body weight in grams	95.6	88.8
Environmental temperature	32.2 °C.	32.2 °C.
Heat production per gram body weight in 24 hours (calories)	0.191	0.283
Per cent heat lost in H_2O	52.3	39.6

A summary of all the data for Age Class C poults, where superior birds of both kinds were carefully selected for metabolism tests, immediately shows an increase in heat production both total daily and per square meter of body surface. The metabolic level observed was distinctly above that in other age classes.

Class D Poults: Twenty-eight to thirty-six days old. The energy metabolism data for Class D poults are given in Table X in two parts: A and B. In part A, a respiratory quotient of seventy-two one-hundredths was assumed for selected birds after fasting thirty hours. The heavier weight poults described in part B were selected at random from the pen and fasted forty-eight to fifty-two hours. Respiratory quotients of seventy one-hundredths and seventy-one one-hundredths were found for these birds by measurement of respiratory products and oxygen absorption.

Part A

The results of certain Class D experiments, in which additional tests of selected individuals were made, support the data found in Class C experiments. The weights and sizes of the poults had increased materially. The average body temperature shows an increase slightly higher than previously recorded except for those poults examined immediately after feeding. The average respiration was fifty-three per minute, a rate slightly lower than observed in younger poults. During the stage of development, particularly beginning with Age Class C poults, a definite increase in vital functions and a rise in the daily heat production were observed. In comparing the physiological data of birds, consideration must be given to the possible differences in the development of the temperature control mechanism. Edwards (37) distinguished between two groups of birds on a basis of their body temperature at hatching time. Thus, altricial birds borne naked and reared in the nest react differently to environmental stimuli than precocial birds born with a downy covering and capable of leaving the nest soon after hatching.

The margin of physiological distinction between the poults compared in Part A is narrower than in preceding tests. The basal metabolism of the two poults in Class D with an average activity close to one and five-tenths per cent is comparable to the data of the area poults given in Table VII for Class C, whose activity was much higher. This illustrates again the significant role played by the increased muscular activity manifested by the apparently wilder group of poults. In general, the heat values of the two poults in this experiment are approximately the same. There is a slight tendency, however, for increased activity in the area birds, especially as to the greater number of active periods and their more frequent occurrence. The duration of the active periods for the area poult, however, was less than those of the game farm bird.

Part B

In the experiment described in Part A, the effect on metabolism of thirty hours of continuous fasting probably is not significant at an environmental temperature of 32.3 degrees Centigrade (89.9 degrees Fahrenheit) because the body weight and temperature are apparently affected less than in the case of the poults in the Part B experiments. (Table X.) A marked decrease in body temperature and a loss in body weight were observed in poults 44, 45, 48, and 49. The average drop in body temperature was found to be 2.3 degrees Centigrade (4.1 degrees Fahrenheit) for poults 44, 48, and 49 when their average temperature before a fifty-hour fast was was 41.6 degrees Centigrade (106.9 degrees Fahrenheit). The greatest drop in body temperature was observed in area poult 45, where the decrease from the beginning to the end of the fast was about 3.8 degrees Centigrade (6.8 degrees Fahrenheit). This bird was extremely inactive and apparently bordering on a moribund state. Furthermore, the metabolism of poult 45 was considerably lower than previously tested smaller and lighter weight poults. The body temperature of the poults that had fasted only thirty hours showed only a slight decrease as compared to those fasting a much longer time. These data apparently demonstrate the influence of prolonged fasting on the total metabolism of the poults, inasmuch as the body temperature, weight, muscular activity and the metabolic rate are reduced.

TABLE X

The Energy Metabolism of Wild Turkey Poults 28 to 36 Days Old

Type and Number of Poult	Sex	Hours Without Food	Body (Normal) Temperature	Environmental Temperature	Body W'ght	Daily Heat Production		Activity Per Hour			
						Total	Per Square Meter of Body Surface	Total	Active Periods	Frequency of Active Periods	Duration of Active Periods
		Hrs.	°C	°C	Grams	Calories	Calories	Per Cent	Number	Seconds	Seconds
Part A											
GF-38	Q	30	41.5	32.2	151.5	24.21	852	1.4	132	27.3	0.4—
WM-39	Q	30	41.6	32.2	153.6	24.72	862	1.9	171	21.1	0.3+
Part B											
GF-44	O	48	*38.8	31.1	175.19	23.77	759	0	0	0	0
WM-45	Q	52	*37.8	31.1	158.47	20.17	681	0	0	0	0
GF-48	O	48	*39.3	29.0	178.42	29.21	922	0.4	43	84	0.3+
WM-49	Q	50	*39.6	29.0	185.61	26.25	807	0.2	28	128	0.3—

* At end of fast.
Q=male.
O=female.

The variability of the basal metabolism, when computed per square meter of body surface and measured in the upper limits of the neutral temperature zone, seems especially significant in view of the influence on metabolism of prolonged or intermittent starvation.

The respiratory data from the Class D poults in Part B, where the birds were selected at random, suggest the general conclusion that the metabolic rate of the poults in this age group is not significantly different after fasting forty to fifty hours.

Class E Poults: Forty-four to forty-eight days old. In view of the apparent influence of age, body weight and prolonged fasting on the metabolism of younger wild turkey poults, experiments were made to determine the course of the metabolism, activity, body temperature, body weight, and heart rate of older poults during a continuous fast of seventy-two hours.

This type of experiment was made on the assumption that it would be possible to determine the existence of any differences in the environmental resistance of the two types of poults. Therefore, one bird from each group was selected on a basis of the same high standards of physiological superiority as those previously selected. In this case, each bird was distinctly in a better physiological state than any other bird in its respective group. In order to eliminate the possible influence of size and weight on metabolism, birds of approximately the same weight and size were used. The body covering was also comparable. Previous to the tests, both poults had been fed for several days and were later taken from the pen with full crops and in a state of active digestion. The experiments were made on consecutive days, twenty-four hours apart, at a respiratory chamber temperature of 28.0 degrees Centigrade (82.4 degrees Fahrenheit), in the dark, but during the daytime.

The influence of digesting food on the metabolism of animals is well known, but the time required for a post-absorptive condition to manifest itself is known only in the case of a relatively few animals. The period at which active digestion ceases is variable among different species of birds and mammals. An indication of the approximate time an animal first begins to live on the fat reserves of its own body may usually be observed by noting the decrease in the respiratory quotient. In view of the fact that both poults had ingested food containing forty-four and twelve one-hundredths per cent carbohydrates immediately preceding the experiments, a respiratory quotient of one was assumed. Actually, the quotient may have been under or above one. On the other hand, since the passage of food through the digestive tract of the poult is comparatively rapid, a lower quotient, nearer seventy one-hundredths, might be expected after the poults had fasted twenty-four hours or more.

The first experiment demonstrates the specific dynamic action of food on the metabolism. In the case of the "WM" poult, both the total metabolism and activity were higher than the "GF" poult. In the present experiment, the important role played by activity in increasing the heat production in the proportions found, may be clouded by the energy liberated by the digesting food.

The basal metabolism of the two poults for the entire period of starvation is compared in Table XI. The percentage difference in the metabolic rate and other vital processes occurring from the beginning to the end of the seventy-two-hour fast are given in Table XII.

TABLE XI

COMPARISON OF THE BASAL METABOLISM, RESPIRATORY QUOTIENT, ACTIVITY, BODY TEMPERATURE, AND BODY WEIGHT OF GF AND WM POULTS WITHOUT FOOD FOR 72 HOURS

(At environmental temperature of 28.0°C.)

Type of Poult	Age	Hours Without Food	Body W'ght	Heat Production Per Day		R. Q.	Activity Per Hour Per Bird				Fall in Body Temperature	Loss in Body W'ght
				Total	Per Square Meter Body Surface		Total	Number of Active Periods	Frequency of Active Periods	Average Duration of Each Active Period		
	Days		Grams	Cal.	Cal.		Per Cent		Seconds	Seconds	°F	Grams
GF	44	0	365.7	45.18	884	1.00	1.7	155	23.2	0.4		
WM	44	0	371.4	51.12	989	*	3.0	220	16.3	0.5		
GF	45	24	353.0	36.44	730	0.74	0.6	49	73.5	0.4—	1.2	12.74
WM	45	24	356.8	38.02	756	0.73	1.8	159	22.6	0.4—	1.5	14.60
GF	46	48	331.7	34.78	726	0.72	0.9	107	34.0	0.3—		21.30
WM	46	48	325.3	33.89	717	0.70	2.8	200	18.0	0.5—		31.51
GF	47	72	303.5	30.33	671	0.71	0.7	89	40.4	0.3—	2.9	28.11
WM	47	72	311.3	32.46	707	0.71	1.6	157	23.0	0.3—	3.4	13.96

* Respiratory quotient of 1.00 assumed.

At the end of the first twenty-four hours of fasting, the fæces indicated that the poults were either in or approaching a post-absorptive condition. This was verified by the decrease observed in the respiratory quotients for both poults. The decrease in the average heat production either as the total amount per day or per square meter of body surface amounts to approximately twenty per cent during the first twenty-four hours of fast. The average loss in weight is three and five-tenths per cent which was accompanied by a slight decrease in internal temperature.

After forty-nine hours of starvation, a different physiological condition was observed in both birds. The most significant difference observed is the increased losses in body weight over the preceeding twenty-four-hour fasting period. The greater loss in weight apparently was associated with the increased muscular activity which was observed during the second twenty-four hours of fasting. This increase in activity, however, may have been a normal physiological response of the poults in attempting to maintain their internal temperature.

At the end of seventy-two hours of starvation, significant physiological changes were observed in both poults. The birds were drawing heavily upon their body tissues for energy, which in the case of the "WM" poult, resulted in a total loss of about sixteen and one-tenth per cent of the initial body weight and seventeen per cent for the "GF" poult. The respiratory quotients of seventy-one one hundredths representing a fat metabolism were observed at the forty-eighth and seventy-second hour of fasting.

TABLE XII

PERCENTAGE DIFFERENCE IN THE BASAL METABOLISM OF TWO WILD TURKEY POULTS FROM THE BEGINNING TO THE END OF A 72-HOUR FAST

	Type of Poult	Daily Heat Production		Activity Per Hour		Body Temperature °F	Heart Rate Per Minute	Respiration Rate Per Minute	Body Weight Grams
		Total (Calories)	Per Square Meter Body Surface (Calories)	Total	Periods Active				
Per cent decrease from beginning to end of fast	GF	32.8%	24.1%	58.8%	42.6%	2.7%	11.7%	29.0%	16.9%
Per cent decrease from beginning to end of fast	WM	36.5%	28.5%	46.6%	28.7%	3.1%	9.4%	22.6%	16.1%
Per cent difference		+3.7%	+4.4%	−12.2%	−13.9%	+0.4%	—2.3%	—6.4%	—0.8%

The gaseous exchange just preceding seventy-two hours without food apparently no longer represented that of the normally fasting animal but probably that of a starving organism whose general metabolism was being carried on primarily by the organs and tissues of the body competing with each other for survival. This is observed in the pronounced decrease in body temperature and heart and respiration rate. (Table XII.)

A comparison of the hourly diurnal activity records of both poults seems most significant. The activity of the "WM" bird was consistently higher than that of the "GF" bird throughout the entire seventy-two-hour study. The greatest amount of total activity per hour (one and seven-tenths per cent) for the "GF" bird was observed in the first experiment when the total metabolism was measured. The lowest total activity per hour (one and six-tenths per cent) for the "WM" bird was found at the end of seventy-two hours of fasting when a low metabolic rate was recorded.

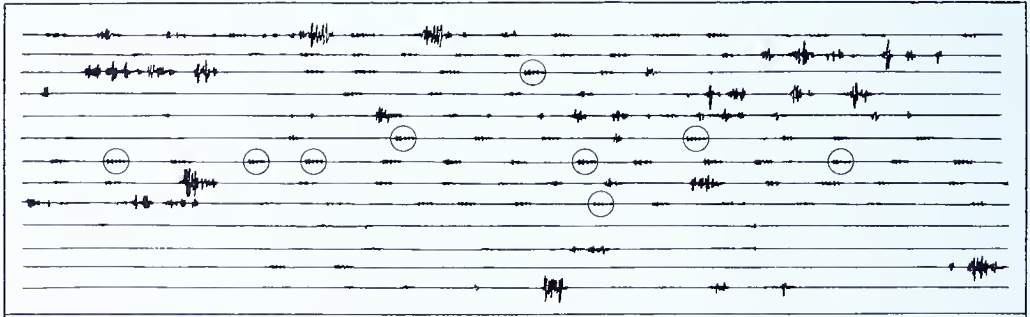
Figure 8. A month-old wild turkey poult.

The influence of muscular activity on metabolism apparently decreased near the forty-eighth hour of fasting since the heat production, body temperature, and other vital functions were no longer maintained at a normal level. A study of the activity with respect to the respiratory quotients found, particularly during the forty-eighth hour of fasting, seems to indicate that increased muscular activity does not noticeably change the respiratory quotient since the quotients were not materially altered.

The data in Table XI shows a progressive decline in the body weight and daily heat production of both strains of poults through the seventy-second hour of fasting. However, the loss in weight and fall in metabolic rate of the "WM" bird is less than the "GF" bird from the forty-eighth to the seventy-second hour. Whether or not the heat production of the poults remains constant after seventy-two hours of continuous fasting is a matter for additional study. However, Long (62) observed a progressive decline in the respiratory exchange of pheasants, quail and Hungarian partridges during the course of prolonged fasting experiments. The decline in the total heat production of the poults following the consumption of food may be due to the gradual dissipation of the extra calories provided by the food eaten and also to the progressive loss in weight of the birds with a corresponding fall in the basal metabolic rate.

Influence of vocal activity on metabolism. Some attention has been given to the influence of singing on metabolism. Groebbels (41) studied the physiology of voice formation in birds. He points out that light, air temperature, and humidity are influential factors in determining the degree and time of singing. Palmgren (72) investigating outdoors the influence of meteorological factors on bird singing and song intensity and found a direct relation with temperature and humidity. From this he assumed that in dry air singing caused a considerable loss of water which was connected with the increased aeration through the lungs and air sacs, thereby causing a decrease in song intensity.

Benedict and Fox (12) raise the question as to whether the metabolism of a singing bird should be compared to nonsinging birds. When the metabolism of canaries was measured, they considered the problem



KYMOGRAPH RECORD NO. 4 (PARTIAL)

ILLUSTRATING RHYTHMICAL USE OF THE "VOICE" BY "WM"
TURKEY POULT NO. 29 DURING A METABOLISM TEST

LEGEND: HORIZONTAL LINES = INACTIVE PERIODS —
VERTICAL LINES = ACTIVE PERIODS — CIRCLES
SURROUND TYPICAL VOCAL EXPRESSIONS

Figure 9.

to be one of sex, since only the male canary sings. Thus, if there was a difference in the gaseous exchange, the higher metabolism would be found in the males. They found a higher metabolism in the male canary at an environmental temperature of 28.0 degrees Centigrade

TABLE XIII

Comparison of the Physiological Effects of Activity and Vocal Expression on the Carbon Dioxide and Water Vapor Output of Two Turkey Poults 20 Days Old

Type of Poult	Body Weight	Surface	CO_2 Per Day	Per Cent Heat Lost in H_2O	Temperature of Env.	Activity Per Hour			
						Total	Number of Active Periods	Frequency of Active Periods	Number of Periods of Vocal Expression*
***	Grams	Sq. Cm.	Liters	Per Cent	°C	Per Cent		In Seconds	
GF-30	109.3	228.60	4.2	42.5	32.2	4.4	432	8.3	None
WM-29	114.2	235.38	4.6	71.7	32.2	8.7	1,080	3.6	*120
						**6.4	600	6.0	

* Each vocal period is equivalent to an average of four chirps or calls.
** Total per cent of activity less all vocal periods.
*** Fasting birds.

(82.4 degrees Fahrenheit) but at temperatures below 25.0 degrees Centigrade (77.0 degrees Fahrenheit), the sexual difference was only slight and practically obscured by the influence of the lower air temperature on metabolism. Baldwin and Kendeigh (3) discuss the influence of singing with respect to changes in body weight of wild birds.

In the turkey work, opportunity presented itself to study the significance of the frequent use of the voice organ during a comparative test in which the metabolism of two poults was measured at the same time at an environmental temperature of 32.2 degrees Centigrade (89.9 degrees Fahrenheit). A section of the record showing the rhythmical use of the voice organ is shown in kymograph record No. 4, page 38. The physiological data is given in Table XIII.

The experimental data of poult No. 29 shows a records of 120 complete vocal periods, each averaging four chirps, or calls, per vocal period, or a total of 480 individual calls per experimental hour. When the percentage of activity represented by vocal expression is deducted from the total activity of eight and seven-tenths per cent for poult No. 29, the total activity values of both poults approximate each other. The difference in the carbon dioxide production which amounts to about sixteen and eight-tenths c.c. per hour and the difference in the heat lost as water vapor amounting to approximately twenty-nine per cent, apparently are accounted for by the difference between the two poults in internal and external activity. The graphic record of activity for poult No. 29 shows that two and three-tenths per cent of the total body movements were apparently due to the use of the voice organ alone. The proportional increase in heat production due to this extra activity, however, cannot be computed. It is apparent, nevertheless, that the greater amount of water vaporized by poult No. 29 may be the result of vocal expression at rhythmical intervals throughout the experiment.

Temperature control. A comparative study of the respiration and pulse rate, gizzard and rectal temperatures was made on seven poults of each type when twenty-two to twenty-four days old. The birds were fasted for twenty-four hours before they were examined, then permitted to feed for a definite period of time, after which their temperature was again taken. The data is given in Table XIV.

TABLE XIV

Comparison of the Heart and Respiration Rate and Body Temperature of Wild Turkey Poults 22-24 Days Old

Type of Poult	After 24 Hours of Fasting			After 10 Hours on Food		
	Gizzard Temperature	Rectal Temperature	Heart Rate	Gizzard Temperature	Rectal Temperature	Respiration Rate
	°C	°C	Per Minute	°C	°C	Per Minute
GF	40.6	40.4	345	41.51	41.38	57
WM	40.3	40.2	348	41.48	41.30	58

The data given in Table XIV was obtained from wild turkey poults with an average energy requirement of one and nine-tenths grams of food and four and nine-tenths grams of water per hour per bird. Under these conditions of food consumption and growth, the poults showed an average increase in weight of two and six-tenths grams per hour per bird per twelve hours of daylight feeding. The fasting poults lost an average of five-tenths gram in weight per hour per bird during a twenty-four-hour observation.

In one experiment the poults were allowed to fast for several hours, at which time the internal temperature was taken. Food and water, previously chilled in a refrigerator, was placed before the poults soon after. Examination of the body temperature shortly after ingestion of the cold food and water showed a slight decrease in body temperature. This decrease, however, was only temporary. In less than two hours after feeding, the body temperature had raised slightly above the fasting temperature first recorded.

Some of the temperature data of the experimental poults has already been reported. Additional daily records were obtained from several poults from thirty hours after hatching to thirty-two days old. These poults had not been subjected to starvation during that period. The average temperature for the thirty-two day period was nearly 41.0 degrees Centigrade (105.8 degrees Fahrenheit). The respiration rate was fifty-eight per minute. At the end of thirty-two days the body weight of these control poults averaged higher than the weight of the experimental poults of the same age. The average body temperature of the experimental poults, taken after feeding, was about 41.5 degrees Centigrade (106.7 degrees Fahrenheit). The lower temperatures found in the control birds is probably explainable partly on a basis of inactivity and less nervous excitement and partly to comfortable living conditions and close confinement. Riddle and Honeywell (80) observed a decrease of nearly thirty per cent in the normal blood sugar of pigeons within three to five weeks as a result of close confinement with inactivity on the part of the birds. Lusk (64) also found the basal metabolism of a dog was markedly lowered after prolonged confinement in a cage even though there was no loss of body weight. This condition was remedied through exercise.

Internal organs. The variations in muscular activity and gaseous exchange observed in the two strains of birds suggested the possibility of variations in the size and weight of certain of the heat producing organs of the body.

TABLE XV

COMPARISON OF THE AVERAGE METABOLISM AND ACTIVITY OF TWO TYPES OF WILD TURKEY POULTS 2-48 DAYS OLD

(Summary)

								Daily Heat Production		Activity Per Hour			
Type of Poult	Age in Days	No. of Poults Used		Without Food (Hrs.)	Env. Temperature (°C)	Av. Body Temperature (°C)	Av. Body Wt. Grams	Total (Calories)	Per Square Meter of Body Surface (Calories)	Total %	No. of Active Periods	Frequency of Active Periods (Sec.)	Av. Duration of Each Period (Sec.)
		O	Q										
GF	2-3	3	9	0	35.5	39.7	42.1	6.28	519	2.9	83.3	43.2	1.25
WM		4	8	0	35.5	39.2	41.6	5.97	501	2.1	98.0	36.7	0.77
GF	5-9	4	3	24	35.5	40.2	51.0	10.61	768	0.8	54.7	65.8	0.52
WM		3	4	24	35.5	40.1	55.7	11.82	806	1.4	99.3	36.2	0.51
GF	15–19	0	3	24	32.2	40.7	88.2	17.19	869	1.3	149.0	24.1	0.30
WM		2	1	24	32.2	40.8	90.5	21.28	1058	5.7	495.0	7.2	0.42
GF	28–36	1	0	30	32.2	41.5	151.50	24.21	852	1.4	132.0	27.3	0.38
WM		1	0	30	32.2	41.6	153.60	24.72	862	1.5	171.0	21.1	0.32
GF	28–36	2	0	50	31.1	39.1*	176.80	26.49	840	0.4	43.0	84.0	0.33
WM		0	2	50	31.1	38.7*	172.04	23.21	744	0.2	28.0	128.0	0.26
GF	44–48	0	3	72	28.0		329.35	33.85	709	0.7	82.0	43.9	0.3+
WM		0	3	72	28.0		331.15	34.79	727	2.1	172.0	20.9	0.4+

* Temperature after fast.
O=female.
Q=male.

Thus, at the age of sixty days, the birds were killed and autopsied in a standard manner. This revealed the fact that the organ ratios of the "WM" birds averaged slightly higher than those of the "GF" individuals.

Summary of physiological data. A comparative summary of the average metabolism and muscular activity for all experiments in all age classes is given in Table XV. A study of this table indicates that domestication apparently influences both the metabolism and behavior of wild turkey poults. The metabolism of the wild-mated area poults reacts to changes in environmental conditions in a greater degree than the game farm poults. Also, the physiological resistance during twenty-four to seventy-two hours of continuous fasting seems higher in the "WM" birds, although it is apparent that the metabolism of both groups of poults was relatively low under the experimental conditions described.

A Comparison of the Physiology of Wild and Domestic Birds and Mammals

Studies on the metabolism of pigeons, doves, and other domestic fowl, as well as certain wild birds and mammals, extend back over a long period of time. Most of the literature on the subject has been reviewed by Benedict and Fox (10, 12), Benedict and Riddle (18), Benedict, Landauer, and Fox (14), and Groebbels (41).

Metabolism experiments dealing with wild game birds are not numerous. Within the knowledge of this investigation metabolism measurements of the wild turkey are not reported in the literature, though Reiset (77) and Richet (78), in their studies on the gaseous exchange of different animals, included a few experiments on three domestic turkeys.

Comparisons of the heat production of wild and domestic animals appear to indicate some differences in their respective metabolic rates. A part of this evidence is presented in Table XVI. Standard methods for measuring the metabolism were used in most of the experiments reported in the table. In them the possible influences of activity and digestion were given due consideration.

Benedict and Fox (12) compared the metabolism of the English sparrow and canary with the metabolism of a wild, free living song sparrow. Their results show a higher metabolism for the wild bird. Also, Riddle, Smith and Benedict (82) show that the feral, migratory, mourning dove has a higher metabolism than either the domestic pigeon or the ring dove.

Benedict and Petrik (17) found the metabolism of the wild Norway rat measurably higher than that of the albino rat, and noted that the metabolic rate declined after the wild animals had become accustomed to handling in the laboratory. Since, as outlined by Gerstell, the original stock of "GF" birds is believed to have been derived from eggs stolen in the wild and since their domestic characteristics may have been brought about by the effects of constant confinement over a period of years, these particular mammalian studies appear of especial significance.

TABLE XVI

COMPARISON OF THE HEAT PRODUCTION PER SQUARE METER OF BODY SURFACE OF DOMESTIC AND WILD MAMMALS AND BIRDS

Species	Average Body Weight (Grams)	Average Heat Production Per Sq. M.* (Calories)	Average Environmental Temperature °C	Strain and Age	Author
Canary	14.6–18.9	738	28.0	Domesticated	Benedict and Fox (12)
English sparrow	21.5–24.0	656	26.0	Semi-domesticated	Benedict and Fox (12)
Song sparrow	22.2–17.6	900	25.4	Wild	Benedict and Fox (12)
Goldfinch	15	997	30.4	Wild	Giaja† (38)
English sparrow	30	924	17.0	Semi-wild	Giaja (38)
Chick	35.6	535	36.0	Domestic (1 day)	Mitchell, Card, Haines (65)
Chick	32.9	551	37.5	Domestic (3 days)	Mitchell, Card, Haines (65)
Chick	40.0	675	29.4–35.0	Domestic (7 days)	Mitchell, Card, Haines (65)
Chick	42.0	567	31.0	Domestic (3 days)	Plaut (75)
Chick	45.5	707	31.0	Domestic (7 days)	Plaut (75)
Mourning dove	114–142	904	20.0	Migratory-wild (mature)	Riddle, Smith, Benedict (82)
Ring dove		792	20.0		Riddle, Smith, Benedict (82)
Pigeon (tippler)	265	680	20.0	Domestic	Riddle, Smith, Benedict (82)
Pigeon (common)	29.6	772.5	29.96	Domestic (3 days)	Riddle, Nussmann, Benedict (81)
Turtle dove	152.0	709	33.0	Wild (mature)	Giaja, Males (39)
Falcon	135.0	646	32.0	Wild	Giaja, Males (39)
Northern bobwhite	175.25	859	28.0	Wild (mature)	Long (62)
Ring-neck pheasant	1389.13	1076	28.0	Wild (mature)	Long (62)
Buzzard (hawk)	600.0	780	21.0	Wild (4-6 weeks)	Groebhels (40)
Wood owl	360.0	730	21.0	Wild	Groebbels (40)
Crow (carrion)	330.0	840	20.0	Wild	Groebbels (40)
Rat	to 292.0	933	28.0	Wild Norway	Benedict, Petrik (17)
Rat	to 375.0	760	28.0	Tame Albino	Benedict, MacLeod (16)
Mouse		640	28.5	Tame Albino	Benedict, Fox (11)
Mouse		1000	28.0	Hairless	Benedict, Fox (11)
Mouse	21.0	520	28.0–34.0	White breed	Benedict, Lee (15)
Mouse	57.0	545	28.0–34.0	Heavy breed	Benedict, Lee (15)
Mouse	8.0	270	28.0–34.0	Dwarf breed	Benedict, Lee (15)
Mouse	19.0	530	28.0–34.0	Wild breed	Benedict, Lee (15)

* Different surface area formulas have been used by the different investigators for computing the heat production.

† Cited by Benedict and Fox (12).

The results of the earlier investigations on the wild rat (17) were confirmed by Benedict and Fox (13) in 1934. They also found that the wild rat succumbed more rapidly during periods of prolonged starvation than did the albino rat.

Another investigation which seems of interest to the present wild turkey work is that of Benedict and Lee (15) who recently measured the gaseous exchange of four races of mice, namely: white, heavy,

TABLE XVII

Comparison of the Relation Between Body Weight and Organ Weight of Birds of Related or Allied Species of Varying Life Habits

Type of Bird	Sex	Age	Body Weight	Heart Ratio	Liver Ratio	Lung Ratio	Author
			Grams	%	%	%	
Northern bobwhite	O	2 months	75.7	0.259	2.23	0.640	Long (62)
Northern bobwhite	O	1½ years	186.6	0.430	1.67	0.208	Long (62)
Arizona scaled quail	O	Immature	90.3	0.731	6.60	0.586	Long (62)
Arizona scaled quail	O	Immature	101.6	0.551	3.80	0.580	Long (62)
Ring-neck pheasant	O	2 weeks	48.2	0.746	2.87		Long (62)
Ring-neck pheasant	Q	2 months	264.4	0.946	3.50	0.461	Long (62)
Ring-neck pheasant	Q	1 year	895.7	0.569	1.12	0.412	Long (62)
Ring-neck pheasant	O	1½ years	1238.2	0.597	1.18	0.711	Long (62)
Ring-neck pheasant	O	2 years	1307.8	0.566	1.21	0.979	Long (62)
English pheasant		Adult	900.0	0.611			Löer (60)
English pheasant		Adult	1000.0	0.700			Löer (60)
English pheasant		Adult	1100.0	0.818			Löer (60)
English pheasant			1205.0	0.744			Löer (60)
Hungarian partridge	Q	1 year	295.6	0.924	1.97	0.386	Long (62)
Hungarian partridge	O	1 year	351.1	1.310	1.95	0.382	Long (62)
Domestic pigeon			340.0	0.882			Löer (60)
Ring dove*	Q O	16 months	157.0		2.01		Riddle (79)
Crow			650.0	1.384			Löer (60)
Tame duck		Adult	2060.0	0.630			Buchanan (29)
Wild duck		Adult	770.0	1.060			Buchanan (29)
Barnyard cock			1336.0	0.680			Clark (34)
Game cock			1663.0	1.030			Clark (34)
White Leghorn cockerel†		2 days	41.1	0.742	3.40	0.860	Mitchell, Card, Hamilton (65)
White Leghorn cockerel‡		58 days	477.0	0.555	2.60	0.550	Mitchell, Card, Hamilton (65)
White Leghorn cockerel		86 days	875.0	0.468	2.30	0.480	Mitchell, Card, Hamilton (65)
White Leghorn cockerel		107 days	1317.0	0.464	1.90	0.520	Mitchell, Card, Hamilton (65)
Wild turkey poult	Q	2 weeks	71.7	0.725	2.57	1.053	Long (62)
Wild turkey poult	O	60 days	1028.4	0.536	2.07	0.612	Long (62)
Domestic turkey			8750.0	0.800			Löer (60)
Domestic turkey			3170.0	1.000			Löer (60)

* Average calculated from data published on 499 male and 444 female birds.
† Average from ten birds.
‡ Average from five birds.
Q=female.
O=male.

dwarf, and wild. A survey of their data seems to indicate that the wild mouse had a higher average maximum and minimum basal metabolism per kilogram of body weight per 24 hours than the other races of mice when measured in a temperature zone of 28 to 35 degrees Centigrade.

Buchanan (29) compared a wild duck weighing 770 grams with a tame specimen weighing 2,060 grams in regard to oxygen consumption, carbon dioxide output, and pulse rate. She found the gaseous exchange considerably higher in the wild duck, but that the pulse rate was lower than that of the tame individual.

The quantitative significance of the heat production of the various internal organs is not definitely known. The metabolic intensity of both organs and tissues probably differs among individuals and species under different environmental conditions.

Brody (25, 26), who conducted extensive metabolism research on both domestic mammals and birds, suggests the possibility that the visceral organs and tissues may be most active under basal conditions. He also suggests that a higher metabolism in wild breeds may be attributed to the relatively greater proportionate weight of the visceral organs.

Benedict (7) discusses the possible effects of varied protoplasmic conditions in the tissues upon the basal metabolism. The investigations of Benedict and Smith (19) show the influence of a greater proportion of muscular tissue upon the metabolism in trained and nontrained athletes. They found that the basal metabolism was higher in the trained individual having a relatively greater proportion of muscular tissue.

On the other hand, Kleiber (54), who agrees with Brody that metabolism should be related to weight, calls attention to the unquestionable influence of active protoplasm on the metabolic rate, but states that it cannot explain the considerable influence of body size on different kinds of animals.

In view of the above opinions, the organ-ratios of wild and domestic birds are compared in Table XVII. The data has been compiled from the literature and is listed according to the method outlined by Clark (34).

A function of the heart is to control the circulation and to some extent the distribution of the blood within the body. By this action both the internal and body surface temperatures of animals are maintained and controlled. Increased activity or emotional excitement may result in an appreciable increase in both the heart and respiratory rates, but in only a slight change in body temperature. Thus, the relation between the heart's size, weight and capacity for blood and the body weight is a significant factor in the measurement of metabolism.

Löer (60) investigated the relation between the weight of the heart and the weight of the body in 483 wild and domestic birds of 56 species. He concluded that wild birds have a relatively larger heart than domesticated individuals.

TABLE XVIII

Comparison of the Frequency of Heart and Respiration Rate and Body Temperature of Domestic and Wild Birds as Reported by Various Authors (a)

Bird	Body Weight	Body Temperature (e)	Heart Rate	Respiration Rate	Notes	Author (b)
	Grams	°C	Per Minute	Per Minute		
Canary	20.0		1000			Buchanan (27, 28)
Goldfinch	16.0		920			Buchanan (27, 28)
English sparrow	24.0		800			Buchanan (27, 28)
Kingfisher	42.0		440		Young	Buchanan (27, 28)
Pigeon	300.0		185			Buchanan (27, 28)
Domestic hen	3000.0		304			Buchanan (27, 28)
Domestic duck	2060.0		240			Buchanan (27, 28)
Wild duck	1010.0		185			Buchanan (27, 28)
Condor				6	Inactive	Bert (22)
Pelican				4	Inactive	Bert (22)
Domestic rooster				12	Inactive	Bert (22)
Dove				30	Inactive	Bert (22)
Sparrow				90	Inactive	Bert (22)
Canary				100	Inactive	Bert (22)
Domestic hen		41.2		20	Average	Löer (59)
Domestic turkey		40.8		14	Average	Löer (59)
Pigeon		42.0		26	Average	Löer (59)
Domestic duck		42.0		22	Average	Löer (59)
Domestic goose		40.5		16	Average	Löer (59)
Domestic turkey	8750 +		93		Average	Stübel (87)
Domestic hen	1980		312		Average	Stübel (87)
Pigeon	2237		244		Average	Stübel (87)
Domestic duck	2304		212		Average	Stübel (87)
Rook	341		380		Average	Stübel (87)
Hooded crow	360		378		Average	Stübel (87)
Buzzard	658		301		Average	Stübel (87)
Vulture	8310		199		Average	Stübel (87)
Falcon	960		347		Average	Stübel (87)
House wren (male)		40.2		112	Average of a large number	Baldwin, Kendeigh (d) (2)
House wren (female)		40.6		92	Average of a large number	Baldwin, Kendeigh (d) (2)
Robin		41.1		45	Average 9 records	Baldwin, Kendeigh (d) (2)
Chipping sparrow		41.1		83	Average 12 records	Baldwin, Kendeigh (d) (2)
N. downy woodpecker		42.8		131	Adult	Baldwin, Kendeigh (d) (2)
Hairy woodpecker		41.7		129	Adult	Baldwin, Kendeigh (d) (2)
English sparrow	13.2	40.9		104	Immature	Long (f) (61)
English sparrow	19.5	42.7		140	Adult	Long (f) (61)
English sparrow	27.1	42.2		94	Adult	Long (f) (61)
Bluejay	69.1	41.7		69	Average 4 records	Long (f) (61)
Bluejay	73.7	42.9		78	Average 6 records	Long (f) (61)
Baltimore oriole	27.3	41.9		107	Average 2 records	Long (f) (61)
Starling		43.2		84		Long (f) (61)
Bronze grackle	100.5	43.0		55	Average 4 records	Long (f) (61)
Red shouldered hawk	306.0	43.0		34	Imm. Aver. 5 records	Long (f) (61)
Barred owl		40.6		142	Adult 6 records	Long (f) (61)
Barn owl		40.4		184	Adult 4 records	Long (f) (61)

TABLE XVIII—(Continued)

Bird	Body Weight	Body Temp- era- ture (c)	Heart Rate	Res- pira- tion Rate	Notes	Author (b)
	Grams	°C	Per Minute	Per Minute		
Great horned owl		41.2		223	Adult 6 records	Long (f) (61)
Black-backed pelican	5090	40.5			Average 2 records	Benedict, Fox (10)
Brown pelican	3510	41.6			Average 3 records	Benedict, Fox (10)
Bearded vulture	5070	39.7			Average 3 records	Benedict, Fox (10)
Great horned owl	1450	39.8			Average 2 records	Benedict, Fox (10)
American bittern	630	39.5			Average 1 record	Benedict, Fox (10)
Domestic turkey		41.2				Löer (60)
Domestic turkey		42.7				Pembrey (73)
Domestic turkey		42.6				Davy (35)
Northern bobwhite	11.4	41.5	504	103	Average 6 records 6 days	Long (61)
Northern bobwhite	75.8	41.8	462	74	Average 6 records 6 weeks	Long (61)
Ring-neck pheasant		36.7	(Hen hatched)		Average 6, 5-80 minutes old	Smith, 1938 (g, f)
Ring-neck pheasant		39.6	(Hen hatched)		Average 6, 5 hours old	Smith, 1938 (g, f)
Ring-neck pheasant	18.3	39.7	(Hen hatched)		Average 13, 20 hours old	Smith, 1938 (g, f)
Ring-neck pheasant	19.6	39.3	Incub.	44	Average 16, 24 hours old	Long (f) (61)
Hungarian partridge	8.7	38.9	Incub.	53	Average 12, 24 hours old	Long (f) (61)
Northern bobwhite	101.2	41.9	322	64	Average 8 records 10 weeks	Long (f) (61)
Northern bobwhite	150.4	43.0		100	6 months	Long (f) (61)
Northern bobwhite	183.2	42.9		117	Adult-trapped	Long (f) (61)
Northern bobwhite	184.2	42.9		139	Adult-trapped	Long (f) (61)
Northern bobwhite	196.4	43.4		142	Adult-trapped	Long (f) (61)
Northern bobwhite		42.6			Average 25 birds	Stoddard (e) (86)
Arizona sealed quail	202.8	43.2		170	Adult	Long (f) (61)
Arizona sealed quail	162.2	42.9		84	Adult	Long (f) (61)
Plumed quail	145.4	43.0	402	89	Adult	Long (f) (61)
Plumed quail	195.0	43.8		92	Adult	Long (f) (61)
Hungarian partridge	310.4	41.9	192	52	Adult	Long (f) (61)
Hungarian partridge	262.4	42.2	264	44	Adult	Long (f) (61)
Pheasant (English)		42.6			Average of Q, O	Löer (60)
Ring-neck pheasant		40.7	298	41	Average 6 records 3 weeks	Long (f) (61)
Ring-neck pheasant		41.9	252	50	Average 6 records 4 weeks	Long (f) (61)
Ring-neck pheasant	2 sexes	43.0	(December)		Average 70 birds	Bennett (21)
Ring-neck pheasant	2 sexes	42.5	(February)		Average 60 birds	Bennett (21)

(a) Reference must be made to the literature for information as to the experimental technique and other conditions under which the physiological records were obtained.
(b) Partial review of the literature.
(c) Chiefly rectal temperatures.
(d) Temperatures taken in proventriculus.
(e) Temperatures taken immediately after death by shooting.
(f) Temperatures taken in gizzard.
(g) Robert Smith, graduate student, School of Forestry and Conservation, University of Michigan.
O=female.
Q=male.

In his study of the physiology of the heart, Clark (34) gives comparative records of the heart weights of a large number of wild and domestic animals. He shows when at rest that, compared to body size, animals with small hearts have a relatively rapid pulse, while animals with comparatively larger hearts have a relatively slower heart rate. Stübel (87) shows the heart beats to be more frequent in small birds than in larger ones. That the heart rate is correlated with vital activity and an important agent in equalizing the body temperature in birds is shown by Groebbels (42), who reviews the literature on respiration, heart rate, and body temperature for a large group of both domestic and wild species of birds. Latimer and Rosenbaum (56) and Latimer (57) made quantitative studies of the weight and length of the body, parts, systems, and organs of 12 bronze turkey hens. They found that the heart had the second highest positive correlation with the body weight, whereas the liver ranked eighth. A smaller positive correlation was found for the lungs and trachea.

A part of the data given in the literature has been reviewed and compiled in Table XVIII, where comparisons are made of the vital activities of a large number of wild and domestic birds.

The significance of the lungs, particularly their weight and size in metabolism measurements is not clearly understood. In birds the lungs and air sacs are the principal organs of respiration supplying oxygen to the blood and removing carbon dioxide and water vapor. Through the process, the lungs become directly involved in the loss of heat from the body. Differences in the frequency of inspiration and expiration in birds probably is due partly to the air capacity and size of the lungs and partly to individual modes of breathing.

In considering the cellular activity of the organs of the body, the functions of the liver are most important. In addition to its action of secreting bile and forming uric acid in birds, the liver has a specia function in metabolism concerned with the formation and storage of glycogen. The glycogen content in the liver has been found to be influenced by muscular activity, body temperature, the kind of food eaten, starvation, and possibly the amount of water ingested. Another function of the liver is the maintenance of the sugar in the blood at a level which meets physiological needs. It has been demonstrated with various animals by a number of investigators that the small supply of glycogen in the liver becomes exhausted during starvation The same condition has been found to exist in wild game birds where determinations were made of the amount of glycogen in the livers of normally feeding and fasting birds.

Long (62) found in metabolism studies at 28.0 degrees Centigrade (82.4 degrees Fahrenheit) that a healthy, normal weight, adult bobwhite had an average daily heat production of 833 calories per square meter of body surface. On the other hand, a bobwhite undergoing prolonged starvation lost 38.23 per cent of its initial body weight within 156 hours. The daily heat production of this bird amounted to only 563 calories per square meter of body surface, a decrease of 32.4 per cent. The liver glycogen of the fasting bird was approximately 80 per cent less than that of the well-nourished bird.

Honeywell (48) demonstrated that blood sugar in pigeons markedly increased when the birds were emotionally excited by sudden or rough handling in the laboratory or by loud noises or talking, and in one case, by a bird flying around the room. In each case emotional glycemia resulted. From this it was concluded that environmental adjustments involve changes in the concentration of blood sugar in the body. In view of the importance of the liver in metabolism, the liver-weight ratios of different birds are given in Table XVII, page 44.

Description of Respiration Apparatus

The metabolism of the two strains of turkey poults was measured in a respiration apparatus especially constructed to study temperature regulation, neuromuscular reaction, body weight, oxygen consumption, carbon dioxide production, and water vapor excretion of birds subjected to controlled environmental conditions.

The whole apparatus consists of the respiration chamber with its several functioning units, the temperature and light control cabinet surrounding it, the absorption train and spirometer. The schematic plan of this apparatus has been described elsewhere by Long (63).

In general, the respiration apparatus is a combination of the open-circuit principle with the closed-circuit principle of Regnault and Reiset (76). This combination allows for the measurement of the carbon dioxide production alone, or direct and indirect measurement of oxygen consumption, vaporization of water, and determination of the weight of the animal in the respiration chamber at any time during an experiment.

In most experiments the open-circuit principle of the apparatus was used to determine the metabolism of the turkey poults. Under these conditions, the animal is sealed in the respiration chamber where the air is constantly changed by a suction pump operating at the end of the ventilating system. The incoming air, drawn to the respiration chamber from the outdoors, or laboratory, by the pump, passes first through a long pyrex glass tube containing absorbents which remove all carbon dioxide (and moisture when desired) from the air before it enters the animal chamber. Hence the air drawn from the chamber contains principally the respiratory products of the animal and the unabsorbed oxygen. After leaving the chamber the air passes through a series of five absorption tubes where the respiratory products are collected for weighing. Leaving the absorption train, the air then passes through an indicator which registers the rate of air flow through the respiration chamber. Finally, the carbon dioxide-and-moisture-free air passes through the outlet pipe of the pump into the laboratory. Thus, in this type of apparatus, the animal is always supplied with a normal amount of oxygen in the circulating current. The amount of oxygen absorbed by the animal throughout an experiment may be indirectly determined by the method originally described by Haldane (44).

The heat production of the poults was measured primarily by determining the carbon dioxide production in experiments where the birds had fasted for at least 24 hours before each test. In some experiments the respiratory quotient was found by determining the carbon dioxide production, water vapor excretion, oxygen consumption, and change in body weight of the experimental poult, or by measuring the oxygen consumption of the poult directly by using a spirometer in a closed-circuit respiration apparatus.

The calorific values of oxygen and carbon dioxide for nonprotein respiratory quotients given by Carpenter (33) were used in calculating the heat production. The results of the experiments are given as the total daily heat production and the daily heat production per square meter of body surface. In calculating the heat production per square meter of surface, the Meeh formula was used, $S=K$ x $W^{2/3}$, where S equals the surface area in square centimeters, K the surface area constant valued at 10 (after Benedict), and W the body weight in grams.

Following the technique of Benedict (8), tests for leaks in the air system were made at different times. The accuracy of the respiration apparatus for measurements of the respiratory products, oxygen consumption, and heat production of animals was demonstrated by making both alcohol and physiological tests. The procedure followed and the results obtained from these tests are described by Long (63).

The respiration chambers, rectangular or cylindrical glass jars with flat, ground flanges, varied in size in order to accommodate different sized poults comfortably and to reduce the volume of air around the specimens.

The covers were of heavy plate glass, ground air-tight on one side, which, when properly installed in the chamber, provided a hermetically sealed container for the cage and bird. In some experiments multiple chambers were used, each containing different strains of wild poults. Thus, the metabolic rate and muscular activity were measured simultaneously under exactly the same environmental conditions.

Each chamber was equipped with a thermocouple for determination of the temperature inside the jar. The thermal junction was attached to the air-exit tube. A mercurial thermometer was also attached to the side of the bird cage at the level of the bird. The humidity of the chamber was obtained through the use of a calibrated hair hygrometer attached to a wall of the glass chamber. Due to the glass construction of the chamber, the poults, thermometer, hygrometer, and activity recording mechanisms are open to inspection at any time. Visibility of the chamber was made possible by the use of special lighting equipment in the control cabinet.

For ventilating purposes a small rotary pump was used to circulate the air throughout the system. It was firmly housed in a container constructed of heavy brass walls where it was immersed in cylinder oil, which served as a cooling medium and as an indicator of leaks in the pump. The temperature of the pump was controlled by circulating cold water through coiled pipes installed in the oil bath. The rate at which air passed through the animal chamber was indicated by a special type of calibrated air-flow meter.

The rate of ventilation varied according to the size and number of poults in the chamber and the objective of the experiment. The ventilating air current used in this work ranged from 500 to 5,000 cc. per minute. When the water vapor given off by the poult was measured, the rate of air passing through the chamber was increased.

The chamber was ventilated for about thirty minutes preceding the time when the air was deflected through the absorbing train. The period of preliminary ventilation depended somewhat upon the time required for the respiration chamber temperature to approximate that of the control cabinet. During the time required to balance the temperature of the chamber and the cabinet, the bird in the chamber usually accustomed itself to cage conditions.

Figure 10. Wild turkey hen on nest.

The bird cages used in the turkey work varied in size, but corresponded to that of the different specimens and the respiration chamber. Made of light-weight wire, each was suspended from the top of the chamber cover in such a manner as to avoid friction with the walls of the chamber and to prevent "bouncing," which ordinarily might result following a period of activity.

A simplified diagram illustrating the principles used in measuring the activity of the poults is figured elsewhere by Gerstell (Figure 2, page 11), while a complete technical description of the activity recorder and bird cage is given by Long (63). In general, the device graphically records the kind, intensity, and duration of each and every period of activity manifested by the birds in the respiration chamber (Figure 3, page 12).

When metabolism tests of the two strains of turkey poults were made at the same time, two respiration chambers and two sets of activity recorders were used. The graphic records of activity of the two poults under these conditions were made on the same kymograph paper, one above the other, permitting quick comparisons of the activity of the birds.

The temperature and light control cabinet is designed to produce and maintain constant environmental conditions within the respiration chamber during metabolism tests.

Approximately forty inches long, thirty inches wide, and thirty-four inches high, the unit is insulated with three inches of cork, which greatly reduces heat and sound transmission. Temperatures ranging from —40 to +125 degrees Fahrenheit are produced by electrically operated mechanical devices with thermostatic controls. Varied light conditions are afforded by means of electric bulbs operated by rheostats.

Experimental Technique

Muscular activity and environmental temperature

In this report the normal activity of the wild turkey poults is considered to be extremely important from two points of view. The graphic records of activity obtained during an experiment are used both as a basis for comparing the energetic action of the two strains of turkey poults and as a method of determining the influence of muscular activity on the metabolic rate. The results obtained therefrom are regarded as extremely significant in the solution of the original problem.

It is usually customary to measure the basal metabolism of birds either in the dark during the daytime, which has a tendency to restrain normal activity, or in the dark during the night, which further reduces the influence of activity on the metabolic rate.

The metabolism of different wild and domestic birds has been found to be 15 per cent to 50 per cent higher during the daytime than during the night. That such reductions in the metabolism of birds occur during the night is pointed out by Groebbels (40), Terroine and his associates (88), Benedict and Riddle (18), Kayser (51), Bacq (1), Brody (25), Herzog (47), Benedict, Landauer, and Fox (14), Burkard, Dontcheff and Kayser (32), Benedict and Fox (12), and Scharnke (84).

The recent discovery of Barott and his associates (6) that the basal metabolism of newly hatched domestic chicks shows a marked diurnal variation is most significant to this report. They found that the maximum energy metabolism of the chicks occurs at about 8 a. m. and the minimum at about 5 p. m.

In addition to the factors mentioned above, environmental temperature also influences the metabolism of birds. However, the specific efforts of varied environmental temperatures upon the metabolism and behavior of the turkey poults is not reported herewith, as the experiments were conducted in temperature zones where metabolism is believed to be essentially minimum. The significance of these zones in metabolism studies is described by Giaja (38), by Benedict (9), by Benedict and Fox (12), by Kleiber and Dougherty (55), by Barott, Byerly, and Pringle (5), and by Mitchell and Haines (67).

The experimental temperatures maintained in the respiration chamber for poults of different ages are summarized in Table XIX. The humidity of the chamber varied from 60 per cent to 70 per cent, while the carbon dioxide and oxygen content was approximately 1 per cent to 21 per cent respectively. The poults were brooded at the same temperatures used during metabolism tests.

TABLE XIX

RESPIRATION CHAMBER TEMPERATURES USED DURING METABOLISM TESTS OF DIFFERENT AGED TURKEY POULTS

Poult Age (Days)	Environmental Temperature (Chamber or Outside Brooding)	
	°C.	°F.
2–9	35.5	95.9
9–20	32.2	89.9
20–36	31.1	87.9
36–50	28.0	82.4

Since the metabolism of the two strains of turkey poults was measured in an optimum environment where physiological processes are considered to be indepent of ordinary changes in environmental temperature and where the minimum metabolism is believed to prevail, any differences observed in the degree and intensity of activity may be of some importance in differentiating between the strains of poults.

Measurement of activity. Available space will not permit the inclusion of a complete review of the literature on methods used to record the muscular activity of animals in metabolism experiments, but a few are briefly described in the following paragraphs.

Benedict and Talbot (20) were partially successful in measuring the movements of children during metabolism tests when a "work adder device" was used. Mitchell and Haines (68) used a similar method when measuring the metabolism of domestic fowl. They believed the results of the activity records were purely of relative significance, serving to assure the comparability of activity during experimental periods.

A comprehensive description of a method to record activity in metabolism tests is given by Benedict and MacLeod (16). They include a quantitative method for interpreting the activity curve provided from the use of a recording tambour writing pen and a rotating kymograph. The activity record is analyzed on a basis of numerical values assigned to three classes of activity, namely, the Value I represents least activity; the Value II, moderate or intermediate activity, and the Value III, the maximum degree of activity. Dukes (36) used the same values when calculating the activity of domestic fowl during metabolism investigations.

Such evaluations of the cage-activity of animals are based on visual inspection of the activity record. No actual quantitative or qualitative values are reported. The limits where "least activity" becomes "intermediate," or where "moderate activity" is considered "excessive" are not described. Records that show excessive activity during metabolism tests are sometimes disregarded and the heat values resulting from such tests not reported. This is due to the belief that basal metabolism is non-existant when the animal is extremely active. Nevertheless, Benedict and Fox, (12, 14) reported the percentage of muscular activity of birds during metabolism determinations, thus providing valuable data which may be used in comparative studies of animal activity.

The activity record of an animal is usually obtained by the use of glazed paper which has first been smoke-blackened, then placed on a rotating kymograph drum. The body movements of the animals in the respiration chamber are reproduced on the paper through the use of tambours and recording pens. If the animal is quiescent during the experiment, a straight line results on the paper, but when the animal moves the writing pen records the movements on the paper. Another method used in summarizing the amount of cage-activity is that of determining the percentage of experimental time during which the animal is either active or inactive. Thus, this method permits a comparison of the percentage activity of one animal with that of another.

All activity records obtained during the turkey experiments were written on standard cross-section millimeter paper. By the use of such paper and by standardizing the speed of the kymograph, the total activity, the number and the duration of active periods are easily calculated.

A straight line written on the record during an experiment indicated that the bird was inactive. On the other hand, when the poult was active, vertical deviations from the straight line were recorded. The height of these deviations correspond to the intensity of bird movement. Since the lever, fulcrum, and writing pen of each recording device were unchanged during an experiment, it was possible to calculate the intensity of muscular activity by measuring the length of the mark on the record, though this data is not herein analyzed.

By watching at the same time the body movements of the bird in the animal chamber and the pen recording the body movements on the kymograph record, different types of activity may be correlated and classified with different marks on the record. This is illustrated by kymograph record No. 1 shown by Gerstell.

The total activity of each poult per experimental period is expressed as the percentage of time the bird was active in the chamber. The total number of active periods per poult is determined by counting each break or mark on the straight line. The average frequency of occurrence of active periods manifested by the bird is expressed in seconds of experimental time. For example, an active period occurred every 50 seconds per hour of experiment. The average duration of each active period originally recorded in millimeters on the cross-section paper by the use of the writing pen has been reduced to seconds of experimental time and are so indicated in the data. For example, the experimental time for the poult to stretch its neck or indulge in other forms of activity required two-tenths of one second.

Methods of testing. A total of 24 wild turkey poults were used in the investigations. The majority of the experiments were made in the dark between 9:00 a. m. and noon, though a few were made in the afternoon. Thus, the metabolism of birds of the same age from each breeding strain were measured at the same hour of day. The metabolic results of experiments conducted in the light and during the night have not been reported here.

The majority of the tests were made with turkey poults that were in the post-absorptive state, food having been withheld for 24, 30, 48, and 72 hours. Several tests were made immediately after the poults had eaten. The average experimental time was one and one-half hours.

Since the accuracy of metabolism work is primarily dependent on the precise weighing of the animal and the absorption tubes, all weighings were made on a 2-kg. analytical balance sensitive to 0.002 gram. A few weighings were made on heavy duty balance with a sensitivity of 0.06 gram under a load of 5 kg.

Feeding methods. Since the poults were not fed until the third day after hatching, they apparently existed upon the energy obtained from the absorption of yolk material. Hence, the energy metabolism of the birds during this time may not be basal. Barott, Byerly and Pringle (5) state that heat values obtained from domestic chicks under five days of age cannot be accepted as basal values because of the unabsorbed yolk material retained in the birds.

After the third day, food and water were kept before the poults at all times, except that birds selected for metabolism measurement were kept in separate pens without food for definite periods.

The manufacturer's* analysis of the food used is as follows:

Carbohydrates	44.12%
Protein	30.30%
Fat	6.84%
Moisture	9.20%
Calcium	2.25%
Phosphorous	1.06%
Fiber	3.80%
Cod liver oil	2.00%
Ash	9.54%
Nitrogen free extract	40.32%

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* Chapin and Company, Hammond, Indiana.

Summary and Conclusions

1. The heat production and activity of two strains of wild turkey poults *(Meleagris gallopavo silvestris)* have been reported. One strain was produced by mating game farm females with males of the same type (the "GF" birds), while the second arose from the crossing of game farm hens with wild toms (the "WM" individuals).

2. The effects of fasting on heat production and body weight were found to vary with the duration of the fast and the age of the poult. As the fasting period lengthened, there was a noticeable reduction in both factors.

3. A comparison of the average basal metabolism and muscular activity of both types of poults from two to forty-eight days of age was made. Age may affect the metabolic rate, since the heat production progressively increased from the time of hatching. The highest values were obtained from poults fifteen to twenty days of age, though they were maintained at approximately the same level through the thirty-eighth day of life. Also, the total daily heat production, as well as the heat production per square meter of body surface, averaged higher in the wild-crossed ("WM") poults than in the game farm ("GF") individuals. However, since it was determined early in the investigations that even small amounts of muscular activity influenced the metabolism of poults in either group, it is concluded that the higher metabolism of the wild ("WM") birds was primarily the result of the greater nervous irritability and muscular activity exhibited by members of this group. The average difference in the total activity per experimental hour in all experiments and all age classes approximates forty-two per cent, favoring the wild-crossed ("WM") birds.

4. The degree of physiological distinction between two closely related groups of wild birds is obviously difficult to measure. Nevertheless, it is concluded that the wild-mated ("WM") poults are more suitable for restocking turkey ranges and better fitted to meet present-day recreational requirements than the game farm ("GF") birds, simply because the former represents a physiological strain which is somewhat different from the latter with respect to environmental reactions and functional properties.

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